Astronomers find new evidence that stars of all types and sizes will wind up as the faint, hot, stellar clinkers called

WHITE DWARFS

by Graham Berry

An eight-year study of the faint, hot, stellar clinkers called white dwarfs indicates how stars of many types, ages, and sizes – including our sun – will shrivel into white dwarfs in their old age.

The study of white dwarfs by Jesse L. Greenstein, professor of astrophysics at Caltech, and a staff member of the Mt. Wilson and Palomar Observatories; and Olin Eggen, formerly of the observatories and now at the Royal Greenwich Observatory in England, contains new information about the brightness, temperatures, sizes and surface conditions of nearly 200 of these important little stars. The study also supports the widely accepted theory of how stars evolve.

White dwarfs are significant because they are the dying stars. They are white hot, even though their nuclear fires are extinguished, and they are small – about the diameter of the earth. However, they weigh 200,000 times more than the earth. The matter of which they are made – a peculiar form of degenerate gas, enormously condensed, has a density of 1,000 tons per cubic inch at the center of the star.

All the white dwarfs in the survey are comparatively near because they are too faint to be seen far away. The farthest is about 200 light years distant. The brightest known are intrinsically 100 times fainter than the sun, while the faintest one is 30,000 times dimmer. None is visible without a telescope. They were studied through the 200-inch telescope at Palomar.

Spectroscopic analysis of the light of some of the white dwarfs shows that their gaseous surfaces are composed largely of helium, while others are composed mainly of carbon. Ordinary stars are made largely of hydrogen, and most white dwarfs still have hydrogen at their surface.

Finding helium and carbon dwarfs is evidence confirming the theory of stellar evolution and the concept that different kinds of stars wind up as white dwarfs. These two special kinds of dwarfs represent the end products of two different types of massive parent stars. The larger, according to theory, evolves a further step in burning fuel than does the smaller one, before becoming a white dwarf. In all of them, hydrogen fuel must be completely exhausted except at the surface.

The theoretical picture of stellar evolution is that in stars of moderate size, like the sun, the nuclear fire goes out after the hydrogen "fuel" has been converted into helium "ashes." The more massive the star, the hotter the nuclear fire, the quicker it consumes its fuel, and the shorter its life. In an evolutionary stage where massive stars swell up to 100 times the sun's diameter, the central cores reach temperatures of 200,000,000 degrees Fahrenheit and convert helium into carbon.

After the nuclear fire is extinguished, a star must somehow lose a great deal of material, leaving only its core of "ashes" – helium, carbon, or even heavier elements. These eventually contract under gravity to become stabilized as a white dwarf. Although they have no nuclear fires, they continue to shine for billions of years as they cool off.

The new observational data provide several direct confirmations of what happened inside the original stars. For example, the average white dwarf weighs less than the sun, while the parent stars weighed at least twice as much.

The two astronomers found about an equal number of helium and carbon-rich dwarfs among the smaller and more massive specimens, suggesting that carbon production is quite common. The composition of a few of the most massive white dwarfs is still a mystery. They show no spectral "fingerprints," no atomic lines or molecular bands to disclose their chemical composition. These stars probably have made even heavier elements, and have very high pressures, even in their outermost atmospheres.

Additional evidence supports the theory that white dwarfs evolve from stars of many sizes and ages. Some white dwarfs were formed only a few

Jesse L. Greenstein, professor of astrophysics at Caltech; staff member, Mt. Wilson and Palomar Observatories

million years ago, while others must be nearly 10 billion years of age.

One white dwarf was found to exist in the Pleiades Cluster of stars. All the stars in that cluster are believed to have formed at the same time, only a few million years ago. The one white dwarf among them, according to Dr. Greenstein, "must be the remnant of a very large star that burned its evolutionary candles brightly at both ends."

However, in the Hyades Cluster, whose stars are some 200 million years old, no fewer than 14 white dwarfs were studied.

White dwarfs are found by two main methods. Because they are nearby, their motion through space is detectable as a movement across the sky. When observers of such star movements note a bluish object, they suspect it to be a white dwarf. Drs. Eggen and Greenstein definitely confirmed many of these by colors and spectra.

Still another method of finding them is to make surveys among faint stars for those that look blue. The majority of faint stars usually are red normal dwarfs. Many of these faint blue stars were found to be slow-moving white dwarfs.

An important result of the Eggen-Greenstein survey is proof that white dwarfs occur among all kinds of star populations. Slow-moving stars belong to the young population found in the spiral arms of our Milky Way Galaxy. Very fast-moving objects, speeding by the sun at up to 200 miles a second, come from the remote areas of the galaxy, or even from near its center. These white dwarfs are among the oldest stars, formed soon after the galaxy was born.

The astronomers discovered a second major kind of white dwarf which is twice as large, and probably weighs half as much, as ordinary white dwarfs. These brighter ones appear to be younger stars, perhaps still in the process of evolving, or still losing matter.

One of the unsolved mysteries of the dying stars is how a large star loses enough material to become a white dwarf. One theory is that a massive star suffers some kind of a violent explosion. But the existence of large numbers of white dwarf descendants of massive stars suggests a less catastrophic process. Armin J. Deutsch, staff member of the Mt. Wilson and Palomar Observatories, has suggested that red giant stars expell a large fraction of their mass.

Although white dwarfs are considered the dying stars of the universe, Drs. Greenstein and Eggen believe that none of them has actually expired. The universe is not old enough for any to have faded into invisibility. Even the faintest known of them are still going strong, still white-hot, with surface temperatures of 6,000 degrees.