THE SPACE RACE: THE GEMINI PROGRAM

FIGURE 2-19[46]

Gemini 4 *astronaut Ed White undertaking a spacewalk in June 1965.*

Project Gemini was NASA's second human spaceflight program and the successor to the Mercury program. The objective of the Gemini program was to develop and improve space travel capabilities that would be necessary for the Apollo mission to land on the Moon. The Mercury program had established that a single astronaut could undertake a spaceflight of several hours. The Gemini missions would demonstrate that teams of astronauts could perform on missions lasting several weeks.

The *Gemini 4* mission, which took place in June 1965, involved the first spacewalk by an American astronaut, Edward "Ed" White. The following mission, *Gemini 5*, set a new space endurance record at eight days thanks to new fuel cells capable of powering longer missions. This was notable because a lunar mission would be expected to take about eight days. The later Gemini missions were dedicated to perfecting docking capabilities between spacecraft. *Gemini 8* accomplished the first docking of two spacecraft in orbit but suffered a system failure that necessitated an early return to Earth.

In November 1966, the final Gemini mission, *Gemini 12*, demonstrated that astronauts could work effectively outside the spacecraft for extended periods. By the end of the Gemini program, NASA had developed many of the necessary techniques and technologies for the Apollo lunar missions. Many of the Gemini astronauts, including Neil Armstrong, Edwin "Buzz" Aldrin, Michael Collins, and Jim Lovell, would go on to take part in Apollo program missions.

sequence, known as the proton-proton chain reaction, four hydrogen nuclei are fused into one lighter, helium nucleus. The mass "lost" from the initial protons to the final nucleus is converted into energy and released. There are other more exotic nuclear fusion reactions that allow for the creation of elements as massive as iron.

The energy from the nuclear fusion reactions eventually reaches the star's surface, where it is released in the form of electromagnetic radiation. The amount of energy released in a single nuclear fusion reaction can be calculated from Albert Einstein's famous equation $E = mc^2$, where E represents the energy released, m represents the difference in mass before and after the reaction, and c equals the speed of light. According to Einstein's equation, when many nuclear fusion reactions occur together, enormous amounts of energy are released.

Nuclear fusion reactions occur at a tremendously high rate in order to continually supply a star's energy output. Every second, around 10^{38} reactions occur within the Sun, converting about 4 million tons of matter into energy at the same rate. Nevertheless, the Sun is so massive that this extremely rapid output of energy results in effectively no appreciable change in its size or temperature. Over the course of its estimated lifetime of 12 billion years, the Sun will convert only around 0.1 percent of its mass into energy[45]

SUPERNOVAE, SUPERDENSE STARS, AND BLACK HOLES

Supernovae

A **supernova** is a large, violent explosion that takes place at the end of a star's life cycle. Supernovae occur due to changes in the core of a star. There are two primary ways these changes can happen, each corresponding to a different type of supernova. Type I supernovae occur in binary-star systems, which are two stars that orbit the same point. One of the stars, a carbon-oxygen white dwarf, pulls matter onto itself from its companion star. Eventually, the white