PHYSICS

Universe's Most Mysterious Force

One of the most mysterious, yet weakest forces in the universe, the pull of gravity, is now also believed to be responsible for the gravitational collapse of star-like objects.

By ANN EWING

➤ GRAVITATION is the most mysterious—and weakest—force in the universe.

It is weak in comparison to the other three universal forces known. It only seems strong because the earth is such a massive object.

Any child who has fallen from a chair or a tree is sobbing proof of the effect, and force, of the earth's gravitational pull. However, this seemingly strong effect is weak when it is measured between particles.

It is so weak that the force the entire earth exerts upon a particle is equal to the electrical attraction between two unlike charged particles placed three feet apart.

Although gravity and gravitation are often used interchangeably, gravitation properly refers to the universal property of matter to attract, whereas gravity means that attraction as exerted by the earth, sun or another rotating mass.

Most Brilliant Objects in Cosmos

When objects are considerably more massive than the earth or the sun, such as concentrations of a hundred million suns in a relatively small volume of space, gravitational collapse can occur. Such a super-explosion may result in the most brilliant light sources known and yields the greatest energy yet discovered in the universe, billions upon billions of times greater than that involved in the nuclear fusion of the hydrogen bomb.

The recent discovery of objects, called "quasars," a contraction of quasi-stellar sources, that may be undergoing gravitational collapse is considered one of the most important milestones in the history of astronomy.

Thanks to three of the all-time giants of science—Galileo, Newton and Einstein—scientists can describe and predict the way in which gravitation works.

Scientists are sure of one thing—there is no known practical way to shield against the pull of earth's gravity. Nor can gravity be controlled. If it could be controlled, a gravity shield could lift satellites effortlessly into orbit or on space journeys.

In a sense, however, the effects of gravity can be controlled, and this is done every time an earth-circling satellite is put into orbit. In an orbiting satellite, persons or objects are weightless, or under zero gravity. Of course, the energy required to reach the zero gravity of a satellite is enormous.

Gravity is always pulling on an orbiting satellite. However, as the satellite falls toward the earth, the horizontal velocity with which it was hurled into space by the launching rocket is such that the satellite covers enough distance to always miss the earth.

Actually, there is no physical distinction between orbiting and falling—in both cases the object or person is reacting freely to the pull of gravity. This is in accordance with Newton's laws, the first two of which were stated informally by Galileo.

Newton's three laws of motion can be stated as follows:

1. A body in motion will continue in motion, and a body at rest will remain at rest, unless acted upon by some outside force.

2. Change of motion is proportional to the force that acts on a body and takes place in the direction of this force.

3. To every action there is an equal and opposite reaction.

Newton then applied these laws to show there is a force of gravity acting between any two bodies in the universe that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Thus the laws that govern the launching and orbiting of space satellites were known almost 300 years ago—only the energy source was lacking.

The zero gravity attained in an orbiting satellite also can be achieved experimentally for a few seconds in an airplane flying along a path such that the plane's speed and direction are temporarily what they would be in a natural orbit at that altitude.

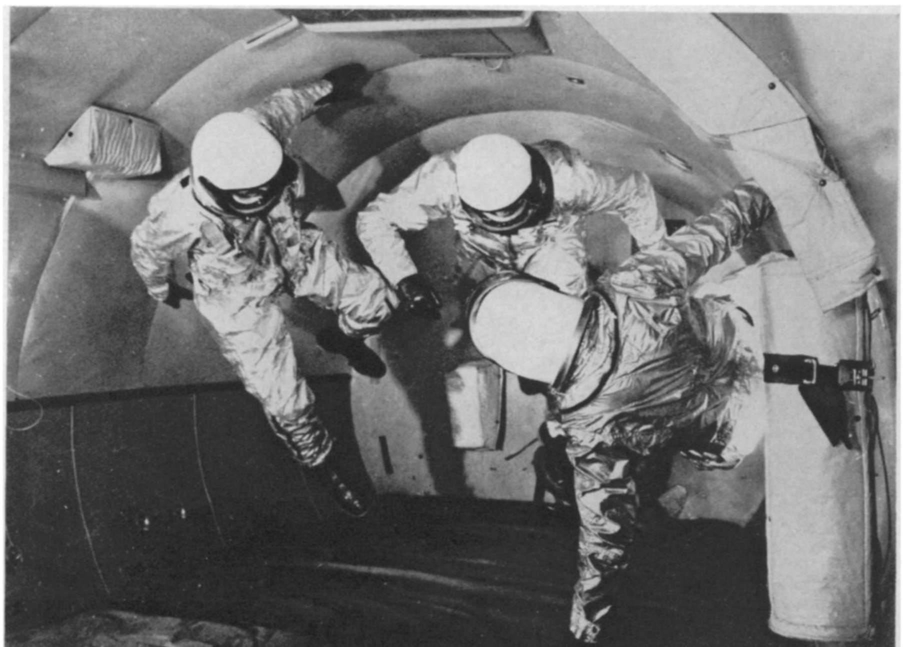
U.S. astronauts and Russian cosmonauts have experienced zero gravity in two situations—when in orbit and during their training when they were in the above-mentioned airplane.

Gravitational attraction is the most widely accepted theory to account for the formation of the solar system's sun and planets. According to this view, the planets are chunks of matter left over when the sun condensed from a giant primeval cloud of swirling dust and gas.

Nuclear Force Is Strongest

However, the great cloud did not go on contracting into a point because of angular momentum, changing the motion of matter from falling to swirling. Other forces may then come into play. One of these forces is electrical. The electrical force of repulsion between two electrons, for instance, is ten thousand billion billion billion billion times stronger than the gravitational force between them.

The electrical force affects only charged particles, whereas gravitational force affects



U.S. Air Force

FLOATING FREE—Two astronauts and their instructor momentarily experience the effects of weightlessness when the pull of earth's gravity has been reduced to zero by an intricate maneuver of the plane in which they are riding. Floating free are, from left, Dr. Edwin Vail of the Air Force Systems Command, Wright-Patterson Air Force Base, Dayton, Ohio, and Astronauts Leroy G. Cooper Jr. and Virgil I. Grissom.

all particles, And the electrical force is weak compared to the extremely strong nuclear force that binds the particles inside an atomic nucleus.

The other known force is that of weak interactions, one example of which is the disintegration of radioactive atoms. This fourth force has a strength between electrical and gravitational forces.

Although the motion of an orbiting satellite is governed strictly by Newton's laws, scientists once proposed using a satellite to make another check of Einstein's relativity theory. Before this was done, however, the effect, called the gravitational red shift, was verified in the laboratory, confirming astronomical observations made on distant stars.

The reddening of light due to gravitation results from the slowing effect that strong gravitational fields have on time, whether time is clocked by the vibrations of atoms or by other rhythmic processes.

Einstein's Influence

Einstein's concept of general relativity brought a revolutionary change in people's ideas about the world. He showed that time and space are not separate, but joined in a framework, and this mesh of space and time is distorted by mass.

One of the basic assumptions of the general theory is that no detectable difference exists between the force of gravity and the force produced by acceleration outside a gravitational field. Measuring the gravitational red shift has confirmed this assumption.

Scientists for the past few years have been investigating the possibility of "quantizing" general relativity, that is, treating gravitational radiation as if it were not continuous but consisted of tiny packets. This can be likened to the situation with light, which many years ago was thought to be continuous radiation but is now known to consist of tiny light packets, or photons.

The packet of gravitational energy is the graviton. Unlike light, which will interact only with charged particles, gravitons can interact with neutral particles.

Detecting Gravity Waves

A device to detect gravity waves is in the final stages of construction by Dr. Joseph Weber and his associates at the University of Maryland. The existence of gravity waves, generated by any mass that is accelerated, is predicted by Einstein's general theory of relativity.

Dr. Weber's device is based on the small effect gravity waves are predicted to have on a relatively large mass. When a gravity wave penetrates the mass, small relative motions of different parts occur, setting up tiny internal oscillations.

These internal jigglings can be converted by crystals and low-noise amplifiers into an electrical output in the radio wave range.

Successful detection of gravity waves would be another proof of Einstein's general theory of relativity. Three effects have so far been verified:

1. Changes in the perihelion (the point closest to the sun) of the planet Mercury's orbit, which observations have shown come very close to prediction.

2. The bending of light from faraway stars by the sun's gravitational field, which comes very close to the amount predicted by Einstein's theory.

3. The displacement, or reddening, of spectral lines due to the gravitational attraction of the sun and certain other stars; laboratory confirmation of this gravitational red shift by measuring the change in frequency of gamma rays given off by iron-57.

Bold experiments on gravitation are scheduled for the future. Some are now in the planning stages. It is, however, difficult to devise new tests because the specific effects of general relativity on matter and energy are very small and hard to measure.

Paper and Pencil Experiments

Another way of attacking the problem of gravitational research is to use not apparatus but the human brain. Scientists with paper and pencil or chalk and blackboard can perform experiments.

Many are using their fertile imaginations to gain insight into how matter and energy are affected by gravitation.

Among these are Drs. Peter Bergmann of Yeshiva University, New York; Hermann Bondi and F. A. E. Pirani of King's College, London; Nobelist P. A. M. Dirac of St. John's College, Cambridge, England; V. A. Fock of the Academy of Sciences of the USSR; Leopold Infeld, director of the Theoretical Physics Institute of the University of Warsaw; Otto Heckmann of the University of Hamburg, Germany; Oscar Klein of the University of Stockholm; Andre Lichnerowicz of the College of France, Paris; Christian Moeller of the University of Copenhagen; A. Schild of the University of Texas; J. L. Synge of the Dublin Institute for Advanced Study, Ireland; and John A. Wheeler, Princeton University.

They are now turning their attention to the gravitational collapse of very large masses. Discovery of the vast energies released by the superexplosion of cosmic dust in objects 100 million times as massive as the sun at fantastic speed has called for a new analysis of the fundamentals of relativity.

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MEDICINE

Find Blood to Be Primary In Hardening of Arteries

➤ EVIDENCE that "fatty plaques" (or hardening of the arteries) are formed from the circulating blood was presented before the annual meeting of the American Heart Association in Atlantic City.

This finding contradicts the popular view that fatty plaques of atherosclerosis must start with initial changes in the artery wall itself, said Drs. I. Ernest Gonzalez and Fred Vermeullen, University of California Medical Center, San Francisco.

Dacron ribbons were suspended in teflon tubes inserted into the chest aorta of rabbits with high fat levels in their blood. The scientists discovered that fatty plaques developed on these ribbons in 150 days. Since the dacron ribbon was in contact only with the blood, it was concluded that these plaques were formed from the constituents of the circulating blood. Similar plaques have been observed by the scientists in synthetic blood vessels grafted into human arteries.

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