The primary gravity science objective of the Dawn mission is to measure the overall mass of Vesta and Ceres and to determine how the mass is distributed in the interiors of these asteroids.

Short flyby missions at great distances can determine the point mass of a body that is infinitely small or an object that can be thought of as infinitely small. When viewed from flyby altitudes, asteroids such as Vesta and Ceres are “infinitely small.”

Since both the gravity and shape models are required to determine the make-up of the interior of Vesta and Ceres, the Dawn spacecraft will do more than just “flyby” the asteroids. For example, when it reaches Vesta, the Dawn spacecraft will assume one of three science orbits:

- In Survey Orbit, the spacecraft will complete an orbit every 68 hours. In this very high level orbit, Vesta will rotate almost 13 times while Dawn makes just one orbit.
- In High Altitude Mapping Orbit (HAMO), the Dawn spacecraft will orbit Vesta every 11–12 hours.
- In Low Altitude Mapping Orbit (LAMO), Vesta will complete only ¾ of a rotation during one orbit of the Dawn spacecraft.

As it orbits Vesta, Dawn’s telecommunications system will take on another role in the mission. Doppler shifts in the spacecraft’s radio signals will be used to measure gravity perturbations, changes in gravity forces. These Doppler shifts will then be used to make “gravity maps” of their mass concentrations.

Radio waves
Radio waves are a form of electromagnetic radiation (EMR), with wavelengths about $10^3$ meters and frequencies ranging from $10^4$ to $10^8$ Hz. Because radio waves are a form of EMR, the wavelength ($\lambda$) of the radiation times the frequency ($\nu$) of the radiation always equals the speed of light ($c$), or $(3.00 \times 10^8 \text{ m/s})$.

$$\lambda \times \nu = c$$

Radio waves are affected by Doppler shifts, a phenomenon that we are familiar with as the change in pitch (frequency) in sound waves of a siren as an emergency vehicle moves with respect to the “observer.” The speed of light (and therefore radio waves) is much greater than that of sound, so Doppler shifts in radio waves are quite small.
Dawn’s telecommunications system allows the spacecraft to exchange information with Earth, even at enormous distances. The spacecraft’s main antenna is 1.52 meter (5 feet) in diameter. Three smaller antennas allow communications when it is not possible or not convenient to point the large dish at Earth. Dawn will communicate with mission controllers through the 34-meter (112-foot) or 70-meter (230-foot) antennas of NASA's Deep Space Network (DSN) in California, Spain, and eastern Australia. For more information about DSN, go to: https://deepspace.jpl.nasa.gov/

Doppler Shifts and Principal Noises
As it orbits either Vesta or Ceres, the Dawn spacecraft will move toward and away from the “observer”, which in this case is a sensitive antenna of NASA’s Deep Space Network (DSN). This motion will cause Doppler shifts in the frequency of its radio signals—a higher frequency “blue shift” as the spacecraft approaches the “observer” and a lower frequency “red shift” as the spacecraft moves away from the “observer.”

Other fluctuations, in the Dawn spacecraft’s radio wave frequencies, called principal noises, can be caused by:

- random errors in the hardware systems in the instrument payload, as well as the
- solar wind, plasma streaming out from the Sun’s corona throughout interplanetary space.

After these shifts and other “noises” have been subtracted and/or calibrated out, fluctuations as small as 1/10th mm/sec in the Dawn’s radio signal frequency can be detected, even when the spacecraft may be traveling at velocities of thousands of km/hr and when it may be located hundreds of thousands km away from Earth. These residual Doppler shifts can be used to measure gravity perturbations as the Dawn spacecraft orbits Vesta and Ceres.

Using Residual Doppler Shifts to Measure Mass Concentration and Mass Distribution
The primary gravity science objective of the Dawn mission is to determine the make-up of the interior of Vesta and Ceres. To do this we must establish the:

- mass concentration, an excess distribution of mass on or beneath the surface of an object, and
- mass distribution, that is, the spatial distribution of that mass.

Since we cannot directly measure the mass of an object in space, such as Vesta or Ceres, we must measure it indirectly by determining the object’s gravity.

As it collects data, the Dawn spacecraft will move in a curved orbit around either Vesta or Ceres. To maintain that curved path, the Dawn spacecraft must have centripetal acceleration, that is, acceleration toward the center of a circular path. This acceleration is supplied by the gravitational attraction of the protoplanet on the spacecraft.

The force of gravity is equal to the mass of an object times its acceleration, \( F = ma \). Any increase in the mass concentration on the surface of an asteroid will exert an extra gravitational force on the orbiting spacecraft, causing additional centripetal acceleration of the spacecraft. Conversely, a decrease in mass concentration will cause a decrease in gravitational force on the spacecraft, and, therefore, a decrease in the speed of the spacecraft.

Doppler shifts actually measure changes in the line-of-sight velocity, that component of the spacecraft’s velocity that is parallel to a line from that body to an “observer” or reference point. Doppler shifts caused by changes in gravity as the spacecraft orbits Vesta and Ceres may correlate with topographical changes; that is, gravity highs usually accompany mountains and gravity lows usually accompany valleys. However, high density is sometimes a subsurface feature; in this case, there may be no surface feature change accompanying this density change.