

## Cosmic Chemistry: Cosmogony

# Dark Matter— More Than Meets The Eye

### TEACHER NOTES: POWERPOINT PRESENTATION

#### BACKGROUND INFORMATION

The PowerPoint presentations, provided as a supplement to the student texts from which they were derived, are always offered in a pdf format for those teachers who do not have the Microsoft® PowerPoint application.

Because teacher use of the presentation slide notes as talking points is vital for complete understanding of the concepts, the slide notes from the PowerPoint are provided here for those teachers using the pdf presentation. Therefore it is important to read and print out these talking points before presenting the material to your students. You may wish to use the [Teacher Guide](#) that accompanies this presentation for additional tips, delivery strategies, and correlation to the national standards.

#### SLIDE NOTES/TALKING POINTS

Slide 1: None.

Slide 2: A similar “discrepant event” has been observed in the universe.

Slide 3: Almost all the mass of our solar system is in the sun. The sun’s gravitational attraction for the planets decreases as the square of their distances from the sun increases. Mercury, whose solar distance is 0.39 of the Earth’s distance, orbits the sun with a velocity of 47.9 km sec<sup>-1</sup>. Pluto, which is 100 times farther from the sun (39 Earth distances, has a velocity of 4.7 km sec<sup>-1</sup>, one-tenth that of Mercury.)

Slide 4: This is a characteristic of all orbital systems where the mass is concentrated inside the orbit. Astronomers *assumed* that the center of a galaxy’s mass was located where the greatest amount of **luminous matter (bright matter—the matter we can see)** was found. Our sun, carrying the planets with it, orbits the center of the Milky Way galaxy with a speed of 200 km sec<sup>-1</sup>.

Slide 5: Scientists now think that this is an indication that most of the mass of the Milky Way is *not* located in the luminous nuclear region, as we previously assumed. It appears that **nonluminous mass (dark matter)** is less concentrated in the center of the galaxy than are the visible stars and gas.

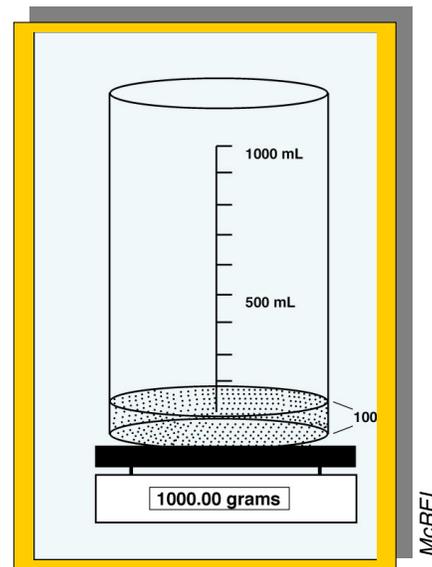
In recent years, theory and observation alike have indicated that at least 90% of matter (and perhaps as much as 99% of the mass of the universe) is **dark matter (nonluminous matter)**, matter that we cannot see. It is invisible, not because it is far away, but because it neither emits nor absorbs light.

Slide 6: Ask students what they think about this possibility. Question them about the reason(s) for their answers.

Slide 7: Evidence shows that the average density of the nonluminous matter at large distances from the center may be as much as 1000 times greater than the mean density of the mass in the universe.

Slide 8: Spectroscopes have been used to study galactic dynamics, emission lines, radio emissions, and x-ray emissions. Telescopes with charge-coupled devices (CCD’s) have been used to detect gravitational lensing events.

The strongest evidence for the existence of dark matter comes from studying **galactic dynamics**, the orbital motions or the rotation of stars and galaxies, using both old and new techniques.





Measurement of the displacements of spectral lines in successive exposures are used to calculate the **velocity** of stars corresponding to that location in the galaxy. [If your students completed the Student Activity, “Doppler Effect—Are you Coming or Going?,” have them recall what kind of motion with respect to the Earth resulted in red and blue shifts. If they have not done this activity, you will want to summarize the background information in the student text that is part of this activity.]

**X-ray** energy, which indicates temperature and velocities of atoms, is also an indication of the lower limit of **escape velocity** of the galaxy. The escape velocity is directly related to the mass of an object, so it can be used to determine the minimum mass of the galaxy. In most cases, the mass turns out to be *10 times* the mass of the visible stars in the galaxy. From this it can be inferred that the galaxy is mostly dark matter.

Slide 9: When light from a quasar travels toward us in space, it may pass to either side of an intervening cluster of galaxies. The warping of space in gravitational fields surrounding the cluster can act as a lens, with the result that we see two images of what is one quasar. The strength of the gravitation field is a measure of how much mass there is in the cluster and where it is centered. This center is usually outside the luminous center, again suggesting that at least some galaxy clusters are primarily dark matter.

Slide 10: Dark objects can actually bend space enough to focus light from distant stars, so that the stars appear to brighten when a dark object passes in front of it. These **microlensing** events, caused by dark objects in the **galactic halo**, can be detected by charge-coupled devices.

How much of the matter in the universe is dark? Since the 1990s, there has been growing acceptance of the idea that perhaps 90% of the mass in the universe is nonluminous. Dark matter appears around individual galaxies and between galaxies in clusters.

Evidence has been found for the presence of lots of dark matter both in the disk and halos of **spiral** galaxies like the one shown in this figure. Studies of the orbital velocity of stars near the sun revealed that there is at least twice as much mass in the Milky Way galactic disk as can be accounted for by adding up all the visible objects it contains.

Studies based on x-ray-emitting gas surrounding giant **elliptical** galaxies in the centers of clusters found that these galaxies are about 90% dark matter. **Dwarf** galaxies have large quantities of dark matter.

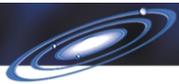
Slide 11: The larger the scale on which we sample the universe, the greater the proportion of dark matter seems to be.

Slide 12: What is dark matter made of? One possibility is that all dark matter is **baryonic**; that is, it is made of protons and neutrons, which are made up of quarks. The term baryons is Greek for “heavy,” so that could help account for the extra mass being observed in the structures of the universe. But, scientists’ mathematical predictions of the total mass of protons and neutrons resulting from the formation of matter in the early epochs of the universe (see Student Text, “Models and Thought Experiments”) make it unlikely that there was enough baryonic dark matter formed to explain the dynamics of a galaxy cluster.

At least some dark matter must be made of familiar baryonic MACHO stuff, but most of it may be of an exotic nature as yet unknown. Remember that in “The Spongy Universe” activity, we found that large voids exist in the cosmos. We do not even know *if* anything is present in the voids. Are they empty of all matter, or only void of baryonic matter?

One suggestion is that dark matter is made up of WIMPS, nonbaryonic forms of matter. Neutrinos were one of the first appealing WIMP candidates for the dark matter. They are nonbaryonic particles that interact with ordinary matter only through the weak nuclear force.

It is thought that lots of neutrinos were released in the events of the early epochs of the cosmos. We found in the Genesis module, “Sun and Solar Wind,” that there is evidence of their formation in the core of our sun. So, neutrinos are known to exist, but it is generally assumed that they have no mass, which doesn’t help us as we try to explain the source of the large proportion of cosmic mass attributed to dark matter.



Slide 13: This is the present state of affairs. We know that there is a great deal of dark matter in the universe. We are fairly certain that most of it is not made of baryons. Some scientists think that there are still some other dark matter candidates that need to be explored.

It may also be that most of the universe is made of dark, nonbaryonic material that is part of a whole universe of shadow matter that exists in parallel with our own. If this is true, the two universes separated when gravity became the major force in our early universe and shadow particles interact with us only through the force of gravity. This makes them ideal candidates for dark matter.

Cosmologists continue to be confronted with a new challenge—to chart dark matter and to identify its characteristics.