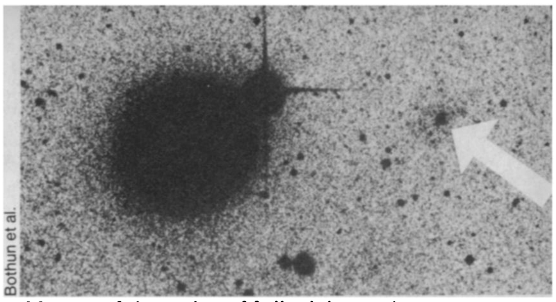
The Dregs of the Universe

Dim galaxies, often overlooked, may represent much more than meets the eye

By IVARS PETERSON



Mystery faint galaxy Malin 1 (arrow).

Astronomers generally focus on the brightest, most spectacular objects in the universe. They search for quasars, supernovas, giant galaxies, massive stars and enormous clouds. But these objects, often studied simply because they're easy to find, may not represent matter typical of the universe.

The dramatic, serendipitous discovery in 1987 of an extremely massive but almost invisible galaxy, dubbed Malin 1, shows how much our picture of the universe may be biased by what astronomers can readily observe (SN: 5/16/87, p.308). The existence of large numbers of galaxies so faint that researchers often overlook them when cataloging astronomical objects could force astronomers to revise their ideas about how stars form and galaxies evolve.

"If there are a large number of these faint objects, they could make a significant contribution to the total mass of the universe," says Gregory D. Bothun of the University of Michigan at Ann Arbor. Bothun, along with Christopher D. Impey of the University of Arizona in Tucson and David F. Malin of the Anglo-Australian Observatory in Epping, Australia, pioneered the study of "low-surface-brightness" galaxies. Bothun describes such galaxies as "the dregs of the universe."

Identifying dim objects against a background of natural faint light from the night sky requires special photographic techniques. One useful method, developed by Malin, depends on the fact that very faint images are recorded only by the uppermost layers of a photographic emulsion, where the grains of silver forming these images are concentrated. Malin amplifies the images by passing diffuse light through the emulsion onto a piece of high-contrast film, greatly increasing the apparent size of the original silver grains.

This technique proved particularly useful for studying a galaxy cluster in the direction of the constellation Virgo, the nearest large collection of galaxies to the Milky Way. Bothun, Impey and Malin hoped to find "dwarf" elliptical galaxies, common but difficult-to-detect members of galaxy clusters. They identified 27 new dwarf galaxies, including one that looked somewhat odd because it featured two distinctive structures: a slightly fuzzy nucleus and a faint outer envelope showing traces of a pattern.

Subsequent observations revealed this unusual, dim object, now labeled Malin 1, as the largest galaxy yet detected. Lying about 715 million light-years from Earth and far beyond the galaxies in the Virgo cluster, its diameter spans at least 770,000 light-years. In comparison, the Milky Way extends merely 100,000 light-years across.

"This is one of the rewards of observational astronomy," Bothun says. "You get to discover something you didn't expect." He and his collaborators have since found a second distant, faint galaxy similar to Malin 1 but only half as large.

Malin 1 is dark because most of its mass still exists in the form of hydrogen gas rather than luminous stars. Although this galaxy contains billions of stars, they lie so far apart that the galaxy as a whole appears faint. Its total light output is substantial but spread out so that no part of the galaxy appears especially brighter than the night sky.

Malin 1 and its more recently discovered sibling are unusual in that they both contain an enormous amount of diffuse hydrogen gas. Most other known low-surface-brightness galaxies seem to have lost their gas clouds, presumably because of the pull of neighboring galaxies. In contrast, Malin 1 seems relatively isolated and has apparently retained its gas. However, its gas density is one-fifth that in star-forming regions of the Milky Way.

In the June 1 ASTROPHYSICAL JOURNAL, Impey and Bothun propose that Malin 1 is a quiescent, nonevolving disk galaxy — a faint giant that has quietly lurked in the background for billions of years without changing very much. After an initial burst of star formation, which created the galaxy's central bulge, no further clumping of matter occurred.

"Both of these low-surface-brightness galaxies have a bulge resembling a normal galaxy that contains a group of old stars," Bothun says. "The galaxy formed this spheroidal component but never continued the process to form a disk of stars. There's this huge cloud of gas surrounding the spheroid that's been sitting there unchanged for the past 10 billion years."

Galaxies like Malin 1 may tell astronomers a great deal about the birth of galaxies. "It is often forgotten that disk galaxy formation can be an unspectacular process that continues to the present day," Impey and Bothun remark in their ASTROPHYSICAL JOURNAL article. Evolution and star-formation rates can be extremely slow. "Our understanding of galaxy evolution will remain incomplete until we have searched for galaxies that have been slow to turn gas into stars," they say.

How common are massive, low-surface-brightness galaxies? "These two [Malin 1 and its unnamed successor] were discovered by accident," Bothun says. "Other examples of these galaxies must exist." But because of technological limitations, the odds against finding such galaxies remain formidable.

Bothun thinks that quiescent galaxies like Malin 1 may represent a significant proportion of the mass of the universe. There may exist billions of dark, "failed" galaxies that never developed beyond the first stages of star formation because much of the hydrogen gas present was too tenuous to clump into stars, he suggests.

Astrophysicists know that stars form out of gas with an efficiency of about 10 percent. In other words, only 10 percent of a collapsing gas cloud ends up in the star. The efficiency of galaxy formation from huge clouds of gas remains unknown, but it's conceivable that this process also leaves behind large amounts of gas. Astronomers have not yet found much leftover galactic material, but low-surface-brightness galaxies may represent one reservoir for this gas.

"Because there has not yet been a large, systematic search for low-surface-brightness galaxies, our knowledge of this hypothetical population is severely limited," Bothun says. Nevertheless, dim galaxies, especially massive ones consisting largely of diffuse gas, may account for a substantial fraction of "dark" matter in the universe. Bright, luminous matter represents only 10 percent of the universe's apparent mass as inferred from gravitational effects.

As an explanation for dark matter, low-surface-brightness galaxies have the advantage that they're within the realm of observational astronomy, Bothun says. It's a way of keeping speculation about dark matter from falling entirely into the hands of particle physicists, who have proposed an array of strange candidates, from weakly interacting massive particles to cosmic strings (SN: 3/4/89, p.138), to account for the missing mass. □