The Search for Unlit Stars

Two years ago, when the first brown dwarf was detected, astronomers thought they could find them in abundance. But now, the discovery is being called into question, and the faint brown dwarfs seem more elusive than ever.

By MARY MURRAY

Shortly before dawn on May 9, 1984, University of Arizona astrophysicist Donald McCarthy Jr. aimed the 4-meter telescope at Kitt Peak National Observatory toward van Biesbroeck 8, a very faint star in the constellation Ophiuchus. Looking at infrared light waves, he found an even fainter companion star — fainter than any star ever detected before or since. It was thought to be the world's first glimpse of a "brown dwarf," a star with so little mass that it never gets hot enough to ignite (SN: 12/15/84, p.373).

Today, however, some astronomers — including McCarthy — are beginning to question whether it was, in fact, a brown dwarf. A group of astronomers who recently looked for VB 8B, as McCarthy's object has come to be known, cannot find it in the place McCarthy found it. And it is unlikely that a brown dwarf the mass of VB 8B could simply have moved a significant distance in just one year.

Michael F. Skrutskie of Cornell University in Ithaca, N.Y., and William J. Forrest of the University of Rochester (N.Y.) looked for VB 8B on July 28, 1985 — a particularly clear night — using instruments at NASA's Infrared Telescope Facility on Mauna Kea in Hawaii. "We didn't see it at 1 arc second away from van Biesbroeck 8, where McCarthy said it was, and we should easily have been able to see it," says Skrutskie. He and Forrest will publish their findings in an upcoming issue of Astrophysical Journal Letters.

McCarthy agrees that Skrutskie's observation calls VB 8B into question. "There's a black cloud hanging over it now, and it's just going to take more work to find out why," he says. McCarthy does not rule out the possibility that VB 8B is not there at all, but says it is more likely that the object has moved to about 1/2 arc second from van Biesbroeck 8. However, he says, if it has moved that much, it is not behaving like a brown dwarf, which would be expected to maintain a constant orbit around its companion star. "If it is what we thought it was two years ago, it's not possible it could have moved that much," he says.

If it turns out that VB 8B is not what McCarthy thought it was, the number of known brown dwarfs will be reduced from one to zero, leaving astronomers with a frustrating lack of evidence for objects that have long been thought to be quite plentiful. Since McCarthy's find, many other astronomers have looked for brown dwarfs in the infrared but have found none — even in cases where star motion studies have suggested brown dwarfs might be there. Others who are studying the initial sets of data from the Infrared Astronomy Satellite (IRAS), a space-based instrument that operated during 1983, also have turned up no evidence of brown dwarfs.

Does it mean that brown dwarfs are just too faint to be seen with conventional instruments? Or is there an unexpected scarcity of them out there?

Astronomers are eager to determine the population of brown dwarfs — partly to figure out whether they can account for the unseen "missing mass" in the universe, and partly to find out more about how stars and planets are formed. If it turns out that brown dwarfs are abundant, it would suggest that celestial bodies can form at any mass in a continuum from small planets to large stars. But if they're scarce, it would suggest that there is some unknown mechanism that keeps objects from forming in a mass range between stars and planets. At this point, most astronomers still believe that brown dwarfs are abundant. After all, they say, there must be some celestial objects that are more massive than planets but less massive than stars (SN: 6/26/82, p.424).

Says William B. Hubbard of the University of Arizona's Lunar and Planetary Laboratory in Tucson, "Right now, we theorists are probably a little hesitant to spin out conjecture on what the paucity of brown dwarfs might mean, because it could be an observational problem."

Astrophysicist John N. Bahcall at the Institute for Advanced Study in Princeton, N.J., is among the many astronomers who believe brown dwarfs could account for missing mass. Bahcall has calculated

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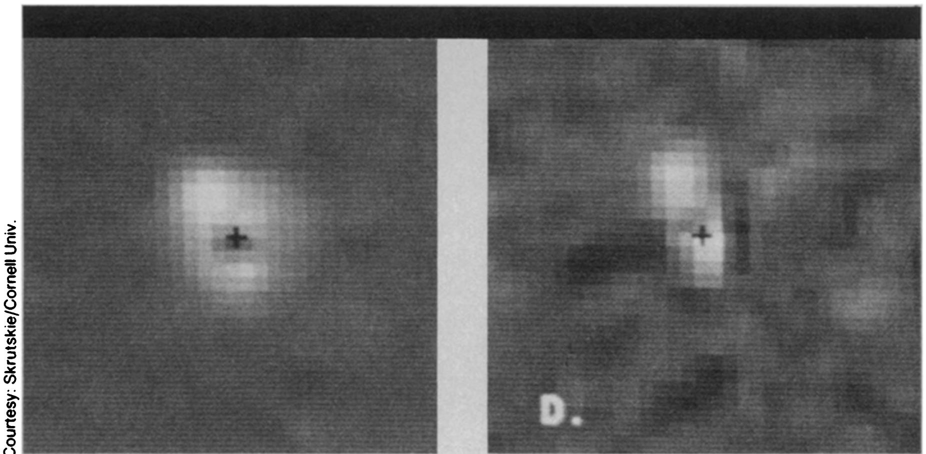
that half the matter in the vicinity of the sun, and 90 percent of all matter in the universe, is unseen. Brown dwarfs, he says, provide a more conservative explanation for missing mass than other theories, such as black holes or unknown, exotic particles. "It's a more familiar concept, a smaller extrapolation from what we know," Bahcall says. "I believe in my guts that the missing matter probably is brown dwarfs, even though we have no evidence yet for the number of brown dwarfs that would be required."

Another reason to suspect that brown dwarfs are plentiful is that low-mass stars are much more numerous than high-mass stars. "It follows that by the time we get down to brown dwarf size, there may be an overwhelming swarm out there," says astrophysicist David C. Black, chief scientist of NASA's Space Station Office in Washington, D.C.

But there are those who are beginning to doubt whether brown dwarfs really are so plentiful. Forrest says his group's inability to locate VB 8B suggests that brown dwarfs are "scarce as hen's teeth or maybe even scarcer."

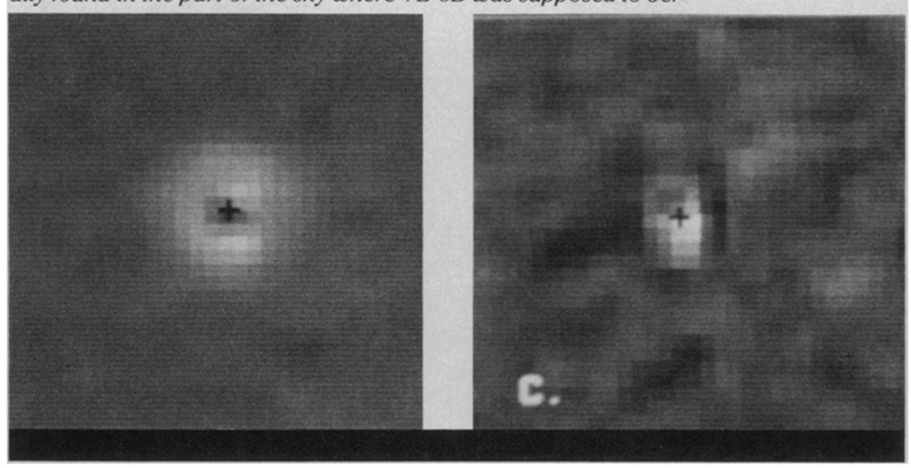
"Brown dwarfs are theoretically easy enough to detect that we should have been able to observe more of them a long time ago if they were common," says John W. Stein of Allegheny Observatory at the University of Pittsburgh. "It's a little surprising to people that we haven't found more of them. . . . The preliminary results right now make it look like they're rare."

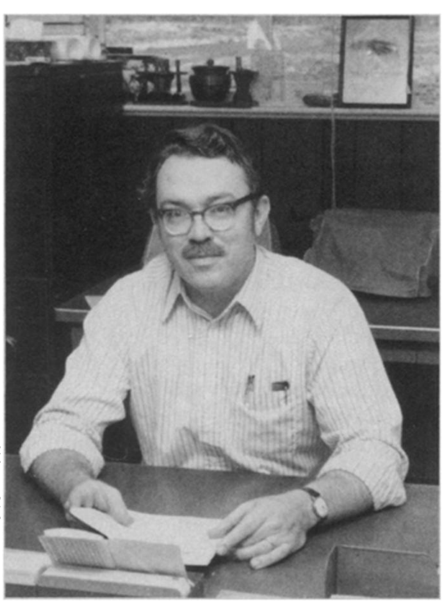
"If a brown dwarf forms the way we think it would, then the fact that we haven't found any is a bit of a puzzle," says Robert S. Harrington of the U.S. Naval Observatory in Washington, D.C., the astronomer who originally pegged van Biesbroeck 8 as a likely candidate for a brown dwarf companion.



Courtesy: Skrutskie/Cornell Univ.

Above, computer representations of how VB 8B should have appeared on Skrutskie's instruments if it were in the location previously described. Below, what Skrutskie actually found in the part of the sky where VB 8B was supposed to be.





U.S. Naval Obs. Photo

Robert Harrington, of the U.S. Naval Observatory in Washington, D.C., identified VB 8B as a star that possibly could be orbited by a brown dwarf.

Most astronomers believe that brown dwarfs form the way stars do, beginning with a swirling mass of hydrogen and helium that gathers into a ball. In a regular star, the gravity that pulls the material together heats it to 10 million° K – hot enough to cause hydrogen fusion, which radiates the light we see in the sky.

In a brown dwarf, theoretically, the mass is too low for gravity to heat the material to the critical temperature. Like a red-hot coal that never catches fire, the object becomes very hot, but never enough for fusion to take place.

The mass required for fusion is believed to be about one-twelfth the mass of the sun. Brown dwarfs are thought to range in mass from slightly less than one-twelfth the sun's mass down to about 10 times the mass of Jupiter. Most brown dwarfs are believed to be about the same size as Jupiter – but at least 10 times as dense.

Because they do not burn hydrogen, but instead cool gradually over time, brown dwarfs are thought to live much longer than stars. "They could last the age of the universe," says Paul C. Joss, an astrophysicist at the Massachusetts Institute of Technology in Cambridge. "Compare that to the sun, which is only 5 billion years old, or about one-third the age of the universe. After another 5 billion years, the sun will use up its nuclear fuel and at least partially blow up and leave behind a white dwarf. Whereas a brown dwarf just sort of sits there and cools, and sits there and cools a little more, and will just stay there forever, cooling gradually."

The word "brown" alludes to the object's theoretical luminosity. Brown dwarfs are believed to give off infrared light in the range between that of a red dwarf (a very small star) and a black dwarf (the object left over after a star has died and its white dwarf has cooled). Astronomers don't know the exact luminosity, and that's why brown – which really isn't a color at all – is an apt description, according to Jill Tarter of NASA Ames Research Center in Mountain View, Calif., who coined the term brown dwarf in 1975 while at the University of California at Berkeley.

In fact, the objects probably would appear yellow-orange, not brown, if we could see them in visible light, according to George D. Gatewood of Allegheny Observatory. That's why Gatewood is among those who prefer to call the objects "IR [infrared] dwarfs." They also are sometimes referred to as "failed stars."

Astrophysicists throughout the world have calculated the theoretical mass, temperature and luminosity of VB 8B,

Painting by William K. Hartmann

Brown dwarfs are thought to form the way larger stars do, beginning with a swirling mass of hydrogen and helium that gathers into a ball. This illustration shows a newly formed star still surrounded by a dusty nebula.

based on what is thought to be its gravitational effect on van Biesbroeck 8, and their measurements generally agree with one another, according to Joss. According to the widely held model, Joss says, VB 8B is about 50 times the mass of Jupiter. It measures about 1 million° K at its center (about one-tenth the temperature of an ordinary star) and about 1,000° K on its surface. And it radiates, in infrared wavelengths, about 3 parts in 100,000 of the luminosity of the sun. These astronomers hope to get more precise measurements of VB 8B's mass by observing the 50- to 60-year orbit of van Biesbroeck 8 for a longer period. That is, if VB 8B is really there and is really a brown dwarf.

So far, the primary method of looking for brown dwarfs has been to begin with astrometric data — measurements of the motions of stars — as McCarthy did. Star motions sometimes suggest that certain stars are revolving in binary systems. When it appears that the companion stars are about the right mass to be brown dwarfs, astronomers can look for them in the infrared. However, in the half-dozen cases of possible brown dwarfs that have turned up in astrometric data so far, astronomers have been unable to detect them, according to Harrington.

A second approach has been to look in the catalogs of the infrared sky that have come from the IRAS. In the initial batches of IRAS data, astronomer Thomas J. Chester of Caltech in Pasadena expected to find about five brown dwarfs. In fact, he found two possibilities, but one turned out to be a red giant (a star at the end of its hydrogen-burning phase), and the other turned out to be the first discovery of an infrared quasar in another galaxy 100 million light-years away (SN: 9/13/86, p.167).

Chester will look again next year, when more IRAS data — three times more sensitive than what he has seen so far — are to be released. In the new catalog, he says, he can expect to find about 20 brown dwarfs. "If we don't find any there, we can say that brown dwarfs don't make up the missing matter," says Chester.

It is best, astronomers agree, to look for brown dwarfs with space-based telescopes — especially those designed to look at a fainter sky than IRAS did. However, that means waiting at least until the space shuttle is back in operation. The Hubble Space Telescope will not be equipped at first for infrared observations, but when it is, it may be able to look for brown dwarf companions to the stars Harrington has singled out.

A more promising space-based instrument for brown dwarf searches is the planned Space Infrared Telescope Facility, which would be able to scan the heavens in search of brown dwarfs both inside and outside of binary systems.

Astronomers may need to wait for these sensitive instruments before they can get a good idea of the population of brown dwarfs. Until then, they will have trouble refining their theories about the evolution and nature of the objects. Says Bahcall, "To learn more, obviously, we must find more brown dwarfs." □

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