Extrasolar Planets, Maybe— But Brown Dwarfs, No

Telltale Doppler shifts have been found in the spectra of certain sunlike stars; yet the most intriguing thing is what the astronomers do not see

A team of Canadian astronomers, using a new high-resolution spectroscopic technique, have obtained what could be the best evidence yet for planets around other stars like the sun.

Speaking at the Vancouver meeting of the American Astronomical Society on 18 June, Bruce Campbell of the Dominion Astrophysical Observatory in Victoria, British Columbia, together with Gordon Walker and Stephenson Yang of the University of British Columbia in Vancouver, announced that their survey of 16 nearby solar-type stars had revealed clear indications of low-mass companions around two of the stars, and suggestive evidence of low-mass companions around five others.

"Low-mass" in this context means one to ten times the mass of Jupiter, a value that is big for a planet—Jupiter contains 318 times the mass of the earth and is by far the most massive planet in our own solar system—yet still quite small for a star. The sun, for example, is 1000 times the mass of Jupiter.

For the moment, at least, the astronomical community is taking a cautious wait-and-see attitude about the new results. "The whole thing will have to stand the test of time," says George Gatewood of the Allegheny Observatory in Pittsburgh, himself a veteran in the search for extrasolar planets. The field has seen far too many "discoveries" that never quite panned out. A good case in point is the much publicized 1984 observation of a companion to the dim red star van Biesbroek 8. The companion has never been seen again, and most astronomers now believe that the original data were spurious.

Nonetheless, says Gatewood, "the new findings are potentially very exciting." Campbell and his colleagues have been conducting their observations for the past 6 years at the 3.6-meter Canada-France-Hawaii telescope atop Mauna Kea in Hawaii. Their approach is based on the fact that a planet will exert a gravitational pull on its parent star, and will therefore force the star to move ever so slightly in synchrony with its orbit. Thus, the planet ought to reveal its presence as a pattern of sinusoidally varying Doppler shifts in the spectrum of the star.

This is hardly a new idea, of course. But in the past it has always foundered on the fact that even a very massive planet will produce velocity shifts of only a few tens of meters per second. (Jupiter, for example, forces the sun to move at about 25 meters per second.) Yet the accuracy of measuring Doppler shifts has traditionally been limited to about 600 meters per second.

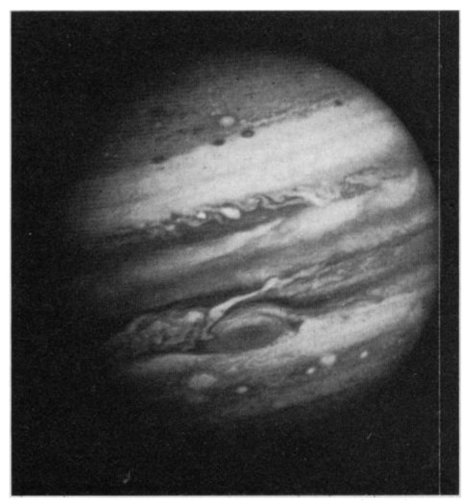
To get around that problem, Campbell, Walker, and Yang changed the tradition. "When you take a spectrum ordinarily," Campbell says, "the wavelength calibration is made from a lamp in front of the telescope." The lamp thus produces a set of known spectral lines at known wavelengths off to one side of the unknown spectrum. "But that won't give you a highly accurate Doppler shift," he says, "because the lamplight doesn't go through the spectrograph in exactly the same way as the starlight." A certain amount of systematic error is inevitable.

For their own work, however, Campbell, Walker, and Yang replace the lamp with a container of hydrogen fluoride gas, inserting it into the telescope in such a way that starlight has to pass through the gas to get to the spectrograph. "The hydrogen fluoride imposes a set of very sharp absorption lines [on the stellar spectrum]," he says. And yet, "optical effects can't displace the two sets of lines because they both follow the same path." The result is a calibration accurate to about 10 meters per second.

With this kind of precision, says Campbell, 2 of the 16 stars in the survey now show evidence for motions at the 4σ confidence level. One of them, as it happens, is Epsilon Eridani, a reddish, fourth-magnitude star of spectral type K2 that is located about 11 light-years from Earth, and that has often been a target in the search for extraterrestrial intelligence. Of the remaining stars, he says, four and perhaps five others show at least some signs of motion.

However, he cautions, there are some caveats. "First, we don't *know* the size of the companions in any of these cases. [We can] only mention in a tentative way that we've detected motions that could be due to massive objects in the 1 to 10 Jupiter mass range."

"Second," he says, "we can't say anything about these objects except their mass. . . . We've only been observing for 6 years. The problem is that Jupiter has an orbital period of 12 years, which suggests that we would have to observe the stars for decades in order to get the full period, mass, and orbital elements of these planets. "


Jet Propulsion Laboratory

A low-mass companion: *If the extrasolar planets observed by the Canadian team are real, they are probably massive blobs of hydrogen and helium gas that closely resemble Jupiter in our own solar system. The photograph shown here was taken by Voyager 1 in 1979.*

Despite these caveats, the project is already proving its worth. "I've always said that finding the first planetary system would make a good news story," says Gatewood. "But the most exciting thing would be to find *groups* of them," as Campbell and his colleagues seem to have done. "That's the science—finding how planetary systems correlate with rotation rates, ages, and spectral types of the stars."

Indeed, perhaps the most intriguing thing about the survey so far is what the Canadian team did *not* see: brown dwarfs, starlike objects that just miss being massive enough to ignite by thermonuclear fusion. According to astrophysical theory, the threshold for thermonuclear burning is about 80 Jupiter masses; a brown dwarf of anything approaching that mass would have stood out in the survey like a searchlight. Campbell is therefore willing to make a categorical assertion: "We've ruled out brown dwarfs between 10 and 80 Jupiter masses."

The Canadians' failure to see brown dwarfs is not altogether surprising, since no one else has seen them either despite a considerable amount of searching. But the new results do lend fresh urgency to a larger question. Low-mass stars are far more abundant in the galaxy than high-mass stars, and a naive extrapolation would lead one to expect that brown dwarfs ought to be even more abundant. The fact that brown dwarfs are rare or nonexistent means that there is something about the star formation process that we do not understand.

"One of the things we're trying to trace is the set of pathways to star formation," says Eugene Levy, director of the University of Arizona's Lunar and Planetary Laboratory in Tucson. Astronomers now believe that all stars are born in essentially the same way inside the galaxy's so-called molecular clouds, which are dense regions of interstellar gas and dust. As the clouds contract by their own self-gravity, the very densest clumps become so massive that they collapse and ignite by thermonuclear fusion. But for some reason, says Levy, there is a bifurcation. On one extreme there are (presumably) embryonic planetary systems like ours, where the infalling gas and dust surround the protostar with a thick, viscous disk. This disk, which is where the planets themselves form, has so much dissipation that everything in it settles into a circular orbit. The image of our own sun's primordial disk can still be seen from the fact that the planets all orbit in the same plane, in the same direction, and in near circular orbits.

At the other extreme, says Levy, there are the systems that go on to become binary or multiple stars; in fact, these multiple systems seem to be in the majority. "Two subcomponents detatch themselves from the inward flow and go on to form separate stars," he says. "From there the evolution of the system is no longer viscous, which means that the two stars are no longer closely coupled." Indeed, the very fact that binary stars tend to circle one another in relatively elliptical orbits means that dissipation never had a chance to erase their infall velocity.

Now, are these two cases just two extremes of a continuum, asks Levy? Do binary systems with one very small member merge imperceptibly into planetary systems with one very large Jupiter? The absence of brown dwarfs, which would occupy that intermediate range, suggests that the answer is no.

But that just leads to another question, says Levy: Why the gap? "One of the reasons for wanting to know the answer," he says, "is because it will tell us something about the dynamics of the gas [in the collapsing cloud]." Especially at the low-mass end, star formation involves a delicate and poorly understood interplay between the one force trying to compress the new star—gravity—and the many forces trying to tear it apart, including pressure, turbulence, magnetic fields, and rotation.

"What's amazing to me is that the lower limit for star formation seems to be so close to the lower limit for nuclear burning," he says. "It's not obvious why that should be. But then, in astrophysics there are a lot of coincidences that people still don't understand." ■ M. MITCHELL WALDROP

Monitoring Earth and Sun by Satellite

Researchers attending the spring meeting of the American Geophysical Union held 18 to 21 May in Baltimore have grown familiar with doing geophysical studies by satellite. Here are three current examples discussed at the meeting: gauging the output of the sun, measuring crustal movement, and deciphering the mineral composition of surface rocks.

How the Sun Faded Even as Its Sunspots Did

The sun has been slowly fading during this decade, even as the number of dark sunspots blemishing its face followed its 11-year cycle to a minimum last fall. Peter Foukal of Cambridge Research and Instrumentation, Inc., in Cambridge, Massachusetts, and Judith Lean of Applied Research Corporation in Landover, Maryland, reported that the sun's fading, when it would seem it should brighten, appears to be a result of the decline of more subtle areas of enhanced brightness. This decline has more than compensated for the decrease of sunspots, they say. The sun's brightness is liable to begin increasing as a new cycle begins, but Earth was probably not so lucky during the Little Ice Age of the 17th century.

Although they doubt that the decline of the sun's total output began as early as 1978, as some observations suggest, Foukal and Lean confirm that two different satellite radiometers have measured a decrease of solar irradiance of 0.07% from 1981 to 1984. A decrease as small as 0.1% lasting a decade might change global climate perceptibly. The earlier reported decrease may have been due to an unintended break-in period of the radiometers, they say, but the recent decrease is certainly real. In support of that contention, they cite the consistent response of the two radiometers—called ERB and ACRIM—from 1981 to 1984. In addition, irradiance changes measured by the two instruments over periods of 4 to 9 months correlated with each other as well as with changes in the structure of the sun's surface.

Foukal and Lean believe that they have pinned down just which changes in the sun's surface caused the sun's recent dimming. Sunspots would seem to be the most obvious candidates. They can contrast so much with their hotter, brighter surroundings that the unaided eye can pick out large ones when the sun is near the horizon. Less obvious but more extensive are the bright areas called plage or faculae associated with sunspots.

Both types of features reflect the snaking of ropes of strong magnetic fields through the visible surface. Sunspots appear dark because their large diameters obstruct the convective flow of heat toward the surface more than they uncover the hotter depths and thus increase their radiation into space. The narrower plage tubes enhance radiation without greatly obstructing convection and are thus bright.

Foukal and Lean found a close correlation between changes in irradiance over 4 to 9 months and measures of the influence of