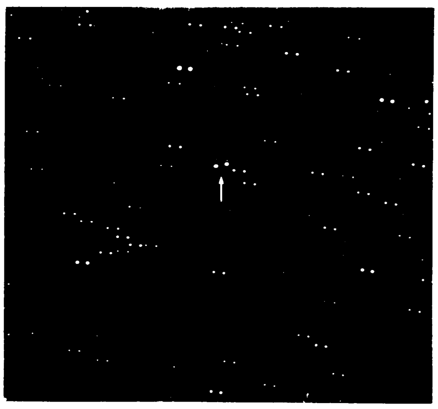
Seeking the Planets of Other Stars

Our planetary system should not be unique, but proving it is difficult



Sproul Obs.

By DIETRICK E. THOMSEN

The sun is a fairly ordinary star. In many respects it can be said to be middle class. The sun is accompanied by nine planets—at least nine planets. If the sun can have planets, it seems that other quite ordinary stars can have them too. Right now astronomers do not have any generally accepted evidence for extrasolar planets. A few alleged cases have been presented and are the subject of vigorous debate. That debate took a few new steps at a well-attended session of the recent meeting of the American Astronomical Society in Troy, N.Y.

Evidence for extrasolar planets is difficult to get and easy to argue about, yet the attitude of astronomers to the basic question of whether extrasolar planets exist, if not to specific pieces of evidence, tends to be favorable. To quote David C. Black of the NASA Ames Research Center at Moffett Field, Calif., who led off the AAS session with a theoretical consideration of why extrasolar planets should be looked for, "Most would vote yes." Sarah Lee Lippincott, director of Swarthmore College's Sproul Observatory, once remarked (of people in general, not only astronomers) that we don't like to think we're alone. That remark can be taken to refer to the bare existence of other planetary systems, to the presence of living beings on them or to both. In any of the senses it probably harmonizes with the feeling of most astronomers that the solar system ought not to be unique in the universe. Unique phenomena are difficult if not impossible for science to handle.

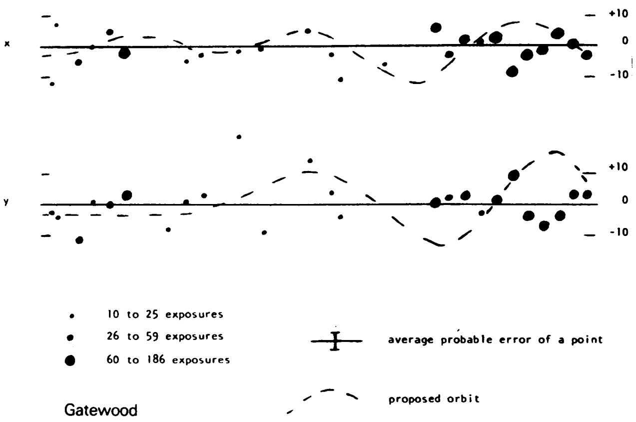
Descending from the realm of generalized philosophy of science, astronomers can make a more specific argument against the uniqueness of the solar system, and Black reminded his audience of it: Nature likes to make astronomical objects in pairs and larger groups. Observation tells us that most stars are members of binary or larger systems. Observation tells us also that at least one planetary system—our own—exists. Suppose there is a continuum of sizes for companion bodies to stars. Some are stars themselves. Then comes a range of dark objects, some classified as stellar size, others getting down to planetary size. (Jupiter is conventionally called a planet, but in some respects can be called a failed star.) Finally the succession comes down to bodies the size of earth or Venus and ultimately even to such cosmic grit as the asteroids.

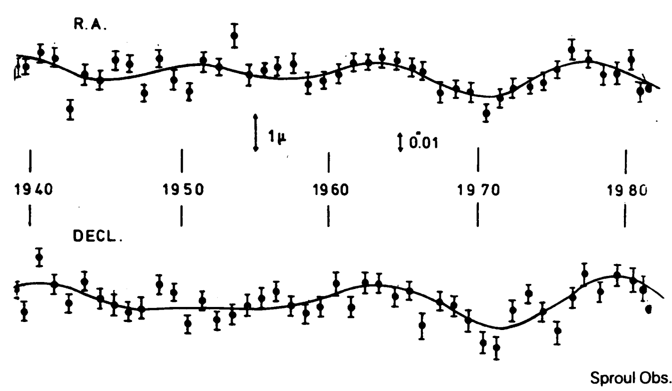
One of the newest pieces of work reported at this session offers evidence for larger-than-planet-sized dark companions for stars. The evidence was obtained by a very new technique, infrared speckle interferometry. The observers, Donald McCarthy and Frank Low of the University of Arizona and Susan G. Kleinman of Massachusetts Institute of Technology, believe that the method will be useful for finding planet-sized companions too.

Thus, two methods, astrometry and infrared speckle interferometry, now claim evidence of dark companions to stars. The third oft-mentioned method, Doppler shift spectroscopy, was the subject of a number of future plans, which, along with instrument designs, were presented at the session by several astronomers.

Astrometry seems to be the oldest technique to be employed in these searches. It is based on the dynamics of a star with a companion. In such a system both objects actually revolve around their common center of gravity, or as the astronomers often say, the common barycenter. Over years all stars show a certain motion across the sky. If the star is traveling with a companion, the revolutions around the barycenter will add a certain wobble or oscillation to this motion. Thus even if the companion is invisible from

Barnard's Star **Yearly mean of three telescopes and the proposed orbit**





Wobble in the motion of Barnard's star determined by van de Kamp (above). Smooth curve shows the cycle he deduces, which would be produced by gravitational pull of two planets, one about four times Jupiter's mass, one about eight times. Data on Barnard's star from Allegheny and Van Vleck Observatories presented by Gatewood (left). Van de Kamp's curve is drawn on the graph, too, to show that it doesn't fit.

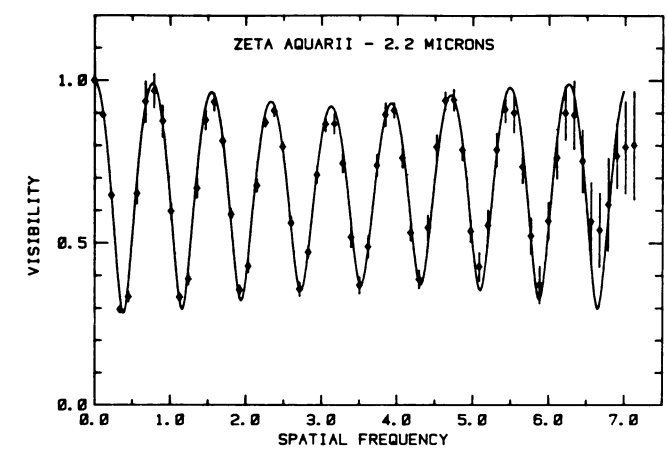
earth, evidence for its existence can be found by noting the wobble in the motion of the visible star.

Given the limitations of telescopes, astrometry tends to work only for quite nearby stars with fairly large companions. Black points out that the sun's motion about its common barycenter with Jupiter has a velocity of 13 meters per second. That leads him to suggest that to find Jupiter-sized companions astrometrically, observers have to be able to separate an oscillating component of around 15 meters per second from the star's other motion, which is measured in kilometers per second. This is possible for only a few stars now, but in the future, especially when and if the space telescope flies, the technique should become more widely applicable.

For now astrometry concentrates on very near stars. One of its chief targets has been Barnard's star, which happens to be the nearest one to us visible in the northern sky. According to Harry Shipman of the University of Delaware, almost everybody who ever worked on Barnard's star was at the AAS session. (Except Barnard himself, who died in 1923.)

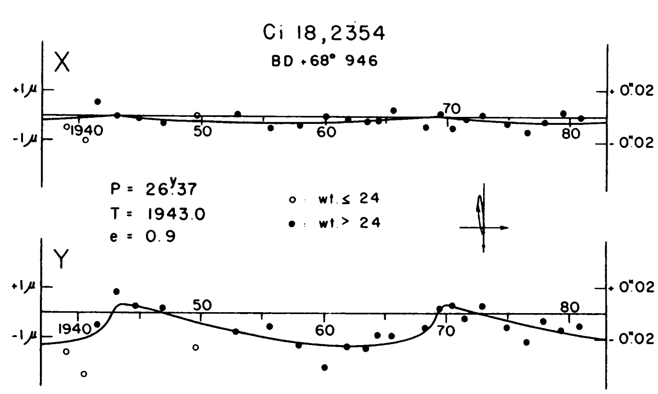
"Continuity is important" in astrometric investigations, says Peter van de Kamp, and he brought forward 45 years of records of the motion of Barnard's star, which he calls with some understatement "one of my pet stars." The records represent 1,200 nights of observing at the Sproul Observatory. Van de Kamp, a member of the Swarthmore College faculty for many years, is now with the Astronomical Institute of the University of Amsterdam. From those 45 years of records van de Kamp has deduced the existence of two planets in orbit around Barnard's star, one with a 20-year period, one with a 12-year period. This conclusion was reached a couple of years ago. If it is correct, the motion of the

Visibility



Visibility versus spatial frequency curve for zeta Aquarii. On this type of graph a single object would show as a straight line at visibility level 1. A double object would exhibit a sine curve with an amplitude related to the distance between the two components. In this diagram there is a sine curve with a smooth variation in amplitude: It is less in the middle and more at the ends. This is the effect of the beat frequency that betrays the small unseen companion accompanying the other two.

Motions of Ci 18, 2354.



Smooth curve shows effect of gravitational pull of apparent planet.

star since then should be predictable from it. Van de Kamp says, "I think the 12-year period shows up in the first point for 1982." The effect of the other period doesn't come out quite as well, but that period is less well determined. It might be anything between 18 and 24 years, he says.

It depends whose observations you use. George Gatewood of the University of Pittsburgh's Allegheny Observatory presented a summation of observations of Barnard's star by the Allegheny Observatory and Wesleyan University's Van Vleck Observatory. From these he reiterated his by now well-known negative or at least agnostic opinion on the presence of planets: "I don't think so. I'm not sure."

Somewhat in the middle is R. S. Harrington of the U.S. Naval Observatory. In response to pressing questioning he said, "I can make [the Naval Observatory data] fit tolerably well" to van de Kamp's graph of the motions of Barnard's star, not Gatewood's. In another session, standing before a poster presentation by himself and V. V. Kallarakal of the Naval Observatory, Harrington exhibited the points representing the recent motion of Barnard's star as determined at the Naval Observatory and said these had led him from skepticism about van de Kamp's conclusions to a more favorable view. Harrington's and Kallarakal's paper also lists two new stars that show "evidence of an astrometric perturbation," that is, the beginning of a suspicion of something, G208-44 and L850-62.

Lippincott, who worked with van de Kamp for many years, reviewed the Sproul Observatory program of tracing the motions of stars within 5 parsecs of us to look for such "astrometric perturbations." There are 63 stars visible in that volume, grouped in 48 systems. (A three-dimensional model in the lobby of the Sproul Observatory exhibits them.) Twenty-eight of these are on the Sproul program. That is, photographic plates containing images of those stars and going back on the average 38 years are available in the plate library at Sproul. The plates are measured mechanically, and the motions of these stars over the years are charted with respect to reference stars that are chosen to be so far away that they move very little in comparison and can be considered fixed stars for this purpose.

Lippincott reports three stars that are candidates for having unseen companions, and she puts upper limits on the masses of the companions. These stars are the ones cataloged in the Cincinnati Observatory catalog as 18, 2354 or in the *Bonner Durchmusterung,* the catalog of the Bonn Observatory, as BD +68° 946. She first reported the first star in 1977 (SN: 6/5/77, p. 404). She now reports that its recent motion follows a prediction based on the assumption of an unseen companion. The second is EV Lacertae, which could have a companion up to three times Jupiter's mass, and the third, which is actually beyond 5 parsecs, is CC1228, which could have a companion 20 times the mass of Jupiter revolving every 6 years.

Speckle interferometry is a way of getting around the turbulence of the earth's atmosphere and its limiting effect on the sharpness of astronomical photographs. The state of the atmosphere over a given telescope changes on the average 50 times a second. (There are wide variations from place to place, but that is an often quoted average.) Each of these changes shifts the image of whatever the telescope is looking at. Thus, in the usual astronomical time exposure, the image of a star will be smeared into a blob. The image of a planet —if one might be at all visible—would be lost under the smearing of this blob.

Modern fast-film photography can follow the changes, and instead of an undifferentiated blob, yields a pattern of often overlapping speckles. This would not be much of an improvement except that the speckle pattern often has an autocorrelation factor built in. For example, if the observer is looking for a star with a companion, the speckles should come in pairs with a fixed distance between the members of each pair. Each shift of the atmosphere moves the images of the pair together without distorting the distance between them. The computer sorts through the speckles, trying all possible pairings. Statistical analysis shows that the distance that appears in the largest number of trial pairs will be the actual one.

The analysis is done in terms of so-called space frequencies. That is, the variations of dark and light across the images are treated as if they were waves across the space. For example, if the distance between two specks on the image is equivalent to one arc second on the sky, that relationship is treated as a wave with a frequency of one cycle per arc second. Every wave can be represented as the sum or difference of a number of other waves, and the analysis is done by calculating with these component waves. If a number of bodies are very close together in the image, beat frequencies will appear in the analysis, analogous to the beat frequencies that can be heard when two tones close to each other in pitch are ringing together.

Speckle interferometry has been used on visible images for several years. It is now being used in infrared, where it amounts to correlating pairs of hotspots. Infrared is very useful in looking for dark companions to stars. In the infrared, these companions tend to show up better with reference to the primary star than they do in visible light, and so they are less likely to be washed out by the primary. Black points out that the sun is 9 to 10 magnitudes brighter than Jupiter in the visible; in the infrared the contrast is much more favorable to Jupiter.

McCarthy reported on work that he, Low and Kleinman did with the four-meter telescope at Kitt Peak National Observatory on five objects located between 1.8 and 23 parsecs from earth. Three of these had been suspected of having unseen companions from astrometric evidence. McCarthy, Low and Kleinman found infrared evidence for companions for all three. The first of these, zeta Aquarii, is a known double star suspected of having a third element estimated at about one-quarter of the sun's mass. Infrared observation found a beat frequency that indicates the presence of a third object 0.17 arc seconds, or about four times the radius of the earth's orbit (4 a.u.) from the known star zeta Aquarii B. In the case of Cincinnati 986 there is evidence for a companion 0.3 arc seconds or 2.2 a.u. from the primary with a mass of about 8/100 of the sun's mass. Xi Ursae Majoris is a pair of bright stars of spectral class G0, which is suspected of being a quadruple system, and indeed the infrared observations give evidence for two unseen companions. A fourth case, for which there is tentative evidence, is Lalande 21185. In this case the data may represent a close companion or they may represent a resolution of the actual diameter of the star itself. Barnard's star showed nothing in this investigation, but that does not necessarily rule out planets of the sort van de Kamp is talking about.

Spectroscopic investigations are complementary in a sense to astrometric ones. Stars move not only across the sky (proper motion) but toward us or away from us along the line of sight (radial motion). Wobbles in the radial motion should be detectable by the cyclic shift they would produce in the wavelengths of light emitted by the star. So far there are no claims of evidence of planet-sized companions by this method, but several groups are working on it.

Finding extrasolar planetary systems might provide a place for intelligent aliens to stand, and that has many romantic possibilities. However, as Black points out, the main reasons for the search — planetology and astrophysics — are much less speculative. First, if we find a number of other planetary systems, we have something to compare with our own. Unique phenomena are hard to deal with; science advances by comparisons. If we know more about the range of possibilities, we can better understand what our own solar system has become.

Astrophysical theory ties the formation of stars and that of planets closely together, and so from comparative planetology we would learn about star formation. Current theory of star formation regards the formation of planets as a common by-product of star formation, so, if we cannot find a lot of other planetary systems, Black says, we will have to revise our whole theory of star formation.

Finally, supposing we find extrasolar planets, Black proposes a mission for the space agencies of the 21st century: an automated probe to Barnard's star to visit them. □