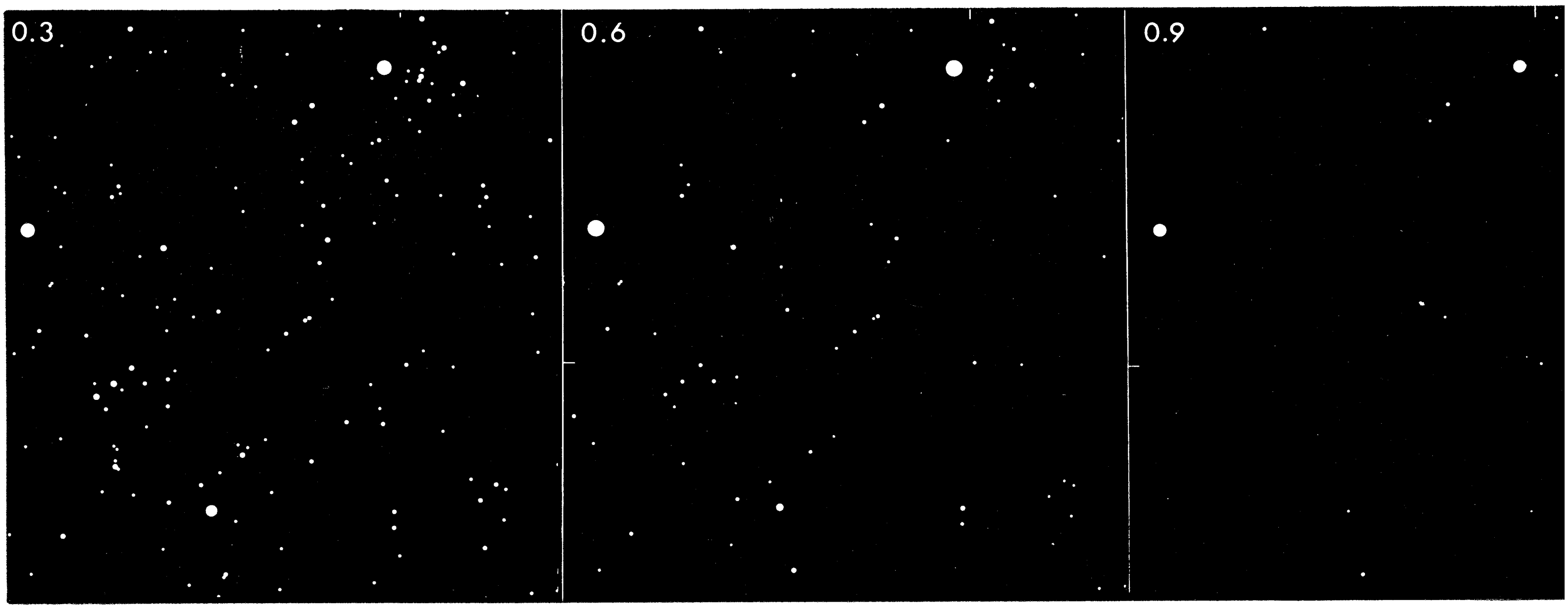

Sky and Telescope

Some stars fade away as speed of space vehicle approaches that of light, due to Doppler shifts toward the ultraviolet.

INSTELLAR NAVIGATION

Calming a navigator's nightmare

Scientists can chart the stars for interstellar flight, though even the sky's signposts will come unhinged

by Ann Ewing

The men who someday may navigate interstellar space will see a fantastic universe where stars change size and color, vanish and reappear according to the speed and direction of the spacecraft. In what appears to be a navigator's nightmare, it is not going to be easy for them to find their way.

Although the problems of navigating among the stars might seem to be strictly the province of the science-fiction writer—and even he does not pay much attention—some scientists are actually giving serious thought to the question.

One who has devoted more time than most to charting paths in this exotic environment is Dr. Saul Moskowitz, now at the National Aeronautics and Space Administration's Electronics Research Center, Cambridge, Mass.

He doesn't concern himself with such simple problems as solar system navigation; on a flight to the moon, such as the Apollo astronauts are scheduled to take before 1970, navigation will be relatively easy. Sightings of landmarks on moon or earth against the background of fixed stars will be used in a computer subsystem to determine the spacecraft's position and velocity.

Interstellar navigation, however, will be much tougher, because the spacemarks will constantly shift. The reference background of stars can no longer be regarded as either infinitely distant, or fixed. The stars must, rather, be considered for what they actually are—a three-dimensional distribution of suns, each with its own motion.

Dr. Moskowitz and his co-workers have calculated the appearance of stars from a hypothetical spaceship traveling at a large fraction of the speed of light, so great that distortions of light will occur and change the apparent shape of the universe. As the spacecraft hurtles onward, the stars ahead of it will appear more blue, those behind it more red, because of the large Doppler shifts involved.

Also, because the wavelength of the light at which each star radiates will appear to have shifted, some stars will appear brightened, others dimmed. An observer aboard such a vehicle will "see a spectacularly changing universe," Dr. Moskowitz believes.

Viewed from within the solar system, the stars seem to form stable groupings. Nevertheless, those forming the named constellations are actually at very unequal distances from earth, and a voyage of only a few tens of light years will considerably alter their apparent positions.

While Dr. Moskowitz was at Kollsman Instrument Corporation, Elmhurst, N.Y., he and his co-workers investigated this problem quantitatively. A computer program to generate star maps for any point within the Milky Way galaxy was prepared.

For one illustration, Dr. Moskowitz chose the star 45 Eridani as the destination of a trans-stellar space flight. As seen from the solar system, this star is of fifth magnitude, just visible to the naked eye, and some 466 light years away.

Sky charts developed by Dr. Moskowitz and his associates show the view from both the forward and rear windows as a spacecraft speeds from the solar system to 45 Eridani. The sun would quickly be lost to sight, fading to below visible limits in a little more than 30 light years. During the same time, 45 Eridani would become considerably brighter; by the end of the

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journey, it could dominate the sky, just as the sun does from earth.

At the same time, as the spaceship approaches the speed of light, the relative velocity of the craft and a given star will produce a Doppler shift. An observer approaching the sun at 90 percent of the speed of light will see the sun radiating mainly in the far ultraviolet in which case it would appear just under four magnitudes fainter than it does for an observer at rest.

On the other hand, a very cool star radiating mainly in the infrared for an observer at rest would appear not only bluer but brighter because of the Doppler shift in its wavelength toward higher frequencies. The star maps produced by Dr. Moskowitz portray these changes as well.

The distortions to be caused by relativity are another factor to be taken into account aboard spaceships traveling near the velocity of light. If a voyager is moving at an angle with respect to the line of sight of a star, then the observed direction of the star would be shifted in the direction of motion; stars would appear to coalesce around the aiming point.

As the velocity of an observer increases, the angular shift of the stars observed on either side of the aiming point becomes larger and larger. To an observer traveling near the speed of light, the entire star field is crowded toward the end of the line of flight.

Dr. Moskowitz and his co-workers have calculated and charted this effect for a body heading toward 45 Eridani; their study of interstellar navigation has been reported both to the American Institute of Aeronautics and Astronautics and May's SKY AND TELESCOPE.

Assisting in the computation were Dr. John Heinbockel and Gary Rosenthal; in the star charting, Anthony Turato, and in astronomical guidance, William P. Devereux.

Another scientist, Dr. William Markowitz, looked into the problem of interstellar navigation when he was director of time service at the U.S. Naval Observatory. He concluded that the best bet for determining a spacecraft's position would be to measure the time of eclipse of binary stars, systems in which two stars, often one bright and one dim, revolve around each other, thus producing regular change in apparent brightness.

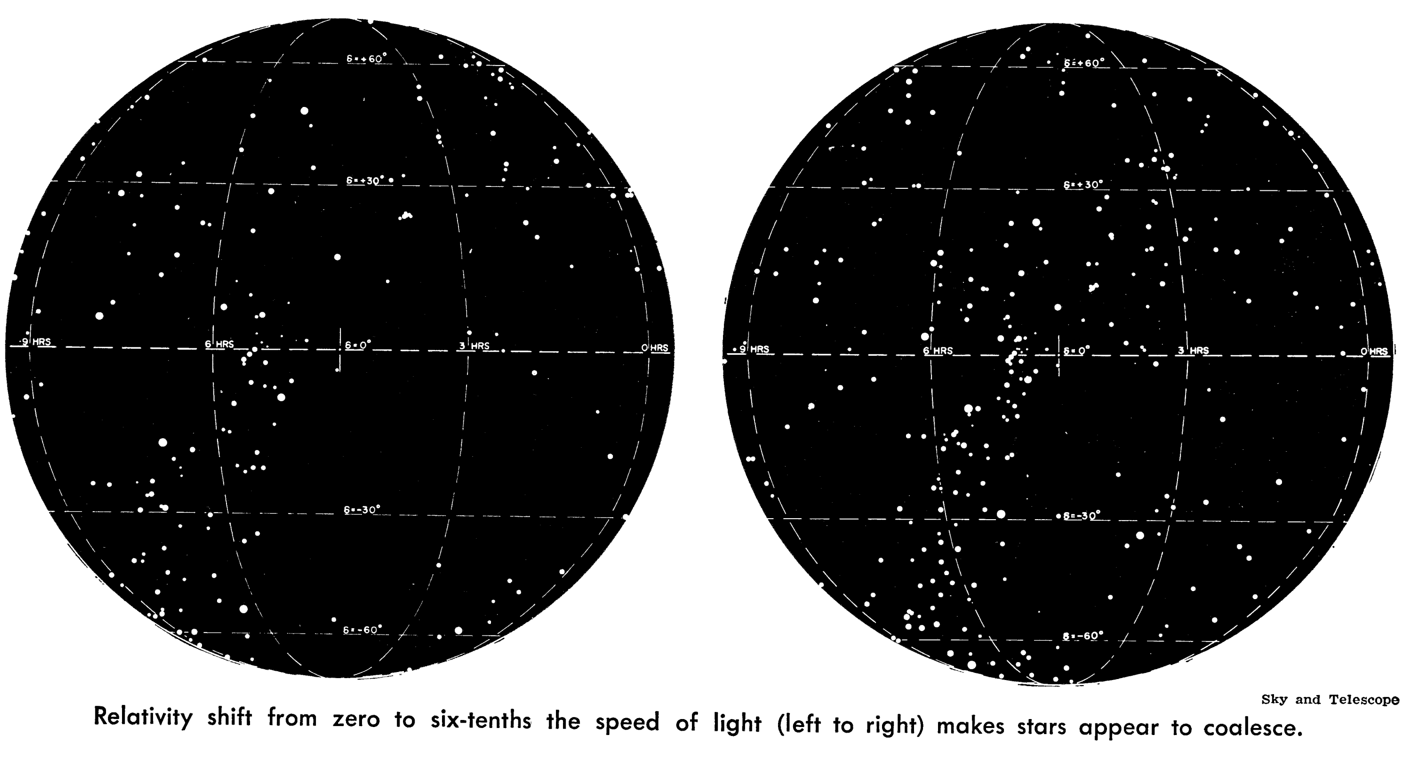
Four quantities are needed by a space navigator to fix his position, three points in space, and one in time. And Dr. Markowitz concludes that fixes on four eclipsing binaries can provide the needed coordinates.

Dr. Markowitz, who is now teaching at Marquette University in Milwaukee, has found that many eclipsing binaries are suitable for space navigation, having light cycles that are complete in one day, as well as a sharp drop in brightness and an equally sharp rise after minimum.

His study showed that a three-inch telescope and a photocell in a spaceship would be sufficient to determine the time of minimum eclipse to between one-tenth of a second and a second; this would determine each of the space coordinates within about 100,000 miles.

Although this uncertainty seems monstrous by terrestrial standards, it is "small in comparison with interplanetary and interstellar distances," Dr. Markowitz notes. Interplanetary distances are measured in hundreds of millions of miles; the distance to the nearest known star, Alpha Centauri, is about 20 million million miles.

Neither planetary positions nor a computer are needed for navigation by eclipsing binaries. Any corrections needed for effects due to relativity could be readily calculated.



Sky and Telescope

Relativity shift from zero to six-tenths the speed of light (left to right) makes stars appear to coalesce.