M-type Dwarf Stars and the "Missing-Mass" Problem

Dr. P. S. Thé *from the Astronomical Institute of the University of Amsterdam is a frequent visitor on La Silla, where he often uses the ESO 1-m telescope for measurements of very faint, red (cool) stars. His research programme is intimately connected with one of the greatest enigmas of modern astronomy: there appears to be more mass in the space surrounding the solar system than we actually observe. Whether this "missing mass" is present in the form of black holes, low-luminosity stars or interstellar material, or whether the theoretical considerations that predict the existence of the "missing mass" somehow are wrong, no one knows for sure. But to solve the problem, more accurate observations are needed. Dr.* Thé *outlines recent research in this field and informs about his programme:*

In 1965, the Dutch astronomer J. H. Oort noticed that some mass is missing in the solar neighbourhood. He announced that the mass density of all known objects near the Sun, including interstellar material, is less than what one can derive semi-theoretically from the movements of nearby stars. This deficiency in mass density (i.e. "missing mass") is about 0.05 $M_\odot/pc^3$ (solar masses per cubic parsec). As simple as this discovery seems to be, yet up till now this problem has troubled the minds of many astronomers.

Search for the "Missing Mass"

S. Kumar was one of the first to suggest that there is plenty of mass hidden in what he called "black" dwarfs. The number of these tiny degenerated stars (masses between 0.02 to 0.07 $M_\odot$) in space is probably very large, but they are too faint to be found easily. Recently, Peter van de Kamp has shown that all unseen companions of normal stars contribute enough mass to solve the missing-mass problem. The weakness of these statistical conclusions lies in the fact that they are based on a small number of stars.

Work based on large numbers of stars by W. Luyten (1968) shows that there is no high space density of red stars of small mass. In fact the luminosity function (relative number of stars with a given absolute magnitude) of these red stars of low luminosity reach a maximum around $M_B = 15^m.5$, and drops again for fainter luminosities. The question is whether this effect is real, or if the decrease of the luminosity function is simply caused by incompleteness of the data; faint stars are generally much more difficult to discover and observe than bright ones.

With this in mind, Donna Weistrop (1972) made an ambitious study of the luminosity function (based on 13,820 stars) in the direction of the North Galactic Pole. The space density she derived for faint red stars was much higher than that of Luyten. Her findings were soon supported by the results of Murray and Sanduleak. The density of 0.23 stars/pc^3 found by these astronomers was about four times higher than that of Luyten, and was quite enough to explain the missing-mass problem. It therefore appeared as if this problem was completely solved.

North-South Discrepancy

However, towards the South Galactic Pole several astronomers obtained different results. Derek Jones, W. Gliese, and Thé and Staller found space densities which correspond closely to those of Luyten: about 0.06 stars/pc^3. This North-South discrepancy is a very serious problem, and the above-mentioned astronomers are often blamed for using incomplete material to obtain their results. The following questions arise: Is the distribution of stars above and below the galactic plane not symmetric? Is the sun not situated in the galactic plane, but to the south of it?

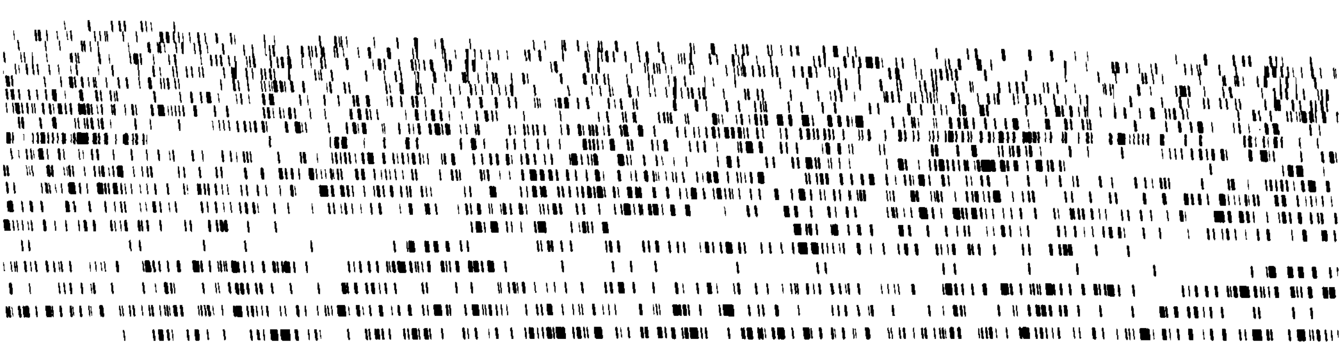
Another serious problem introduced by Murray and Sanduleak is that of the dispersion of the velocities of the M-type dwarfs. They found that their stars not only have small proper motions (<0.″2/year), but also that the dispersion of the velocities of these stars is about half of that of normal M dwarfs. The latter are known to be old population II objects. The assumption that the low-velocity M dwarfs are also old objects contradicts with Spitzer-Schwarzschild's mechanism for the creation of velocity dispersions. Have we then to assume that they are young? Staller explains this problem by the assumption that the low-velocity stars are stars of very low mass, in accordance with the suggestion of Kumar. A rough calculation then shows that these low-mass stars are indeed young objects. If Staller's assumption is correct, then the velocity-dispersion problem is solved.

Theoretically there are more problems in connection with the low-velocity M dwarfs. But this will not be discussed, because recently more observations show that the results by Weistrop as well as by Murray and Sanduleak are erroneous. It turns out that these results are very much influenced by systematic errors in the determination of the colour indices of the red M dwarfs, in such a way that the distances of these stars are estimated too small and that therefore the obtained densities are too high. If these systematic errors are removed, the space densities drop to values similar to those of Luyten

With these important corrections it is now clear that the supposed high space density of M dwarfs is spurious. However, that means that we now are back to the old problem of the "missing mass".

Observations at ESO

Using the ESO facilities at La Silla, we have for many years pursued our study at the Amsterdam Astronomical Institute of very faint red stars (down to magnitude 20 in V) in the direction of the South Galactic Pole. By studying such faint, red stars we hope to obtain a better knowledge of the fainter end of the luminosity function. This again will result in a better understanding of the past history, the birth-rate, and the evolution of these very interesting red stars. It is evident that for reaching the above-mentioned magnitude limit we need a comparatively large telescope, a sensitive and stable photoelectric photometer and equipment for electronographic photometry. There is no doubt that the new ESO 3.6-m telescope will become an important tool for this kind of astronomical research.



A part of the mask for the CORAVEL instrument, here shown in negative. Each line corresponds to a line in the spectrum of a late-type (cold) star. More than 3,000 lines were drawn by a computer programme operating the ESO S-3000 measuring machine in Geneva in a play-back mode. The mask is enlarged several times in this figure.

The CORAVEL

The measurement of radial velocities, i.e. the velocity in the direction of the line of sight, is of fundamental importance in stellar as well as in galaxy astronomy. Until the 1960s the only possible method was to obtain a spectrum on a photographic plate and then measure the displacement of the spectral lines. These observations were extremely time-consuming for faint objects. With the advent of image-intensifying devices, the observing time was drastically reduced, but so was—unfortunately—the accuracy of the measurement, due to geometric distortions in the image tubes. Now, however, the situation has improved very much indeed, as explains Dr. M. Mayor *of the Geneva Observatory, who, together with several European colleagues, is building a spectrometer to determine stellar* radial velocities *by a* correla*tion method.*

The Marseille and Geneva observatories (A. Baranne, M. Mayor and J. L. Poncet) are working together to build two spectrophotometers for stellar radial velocities. Testing of the first machine has been completed. But before giving the results of these tests it could be useful to review the principles of operation of these "spectrovelocimeters".

In the last ten years, the field of stellar radial velocities has been enriched by a new method whose efficacity and precision for late spectral type stars is exceptional. The development of this method and the proof of its reliability are due to R. Griffin at Cambridge. He has been able to measure the radial velocity of a 14th B-magnitude star to within 1 km/s in only 4 minutes at Palomar!

The Doppler shift measurement is done by means of an optical cross-correlation between the stellar spectrum and a mask located in the focal plane of the spectrograph. This mask is designed to stop photons coming from the stellar continuum and is transparent in the regions of the absorption lines. The spectrum is scanned across the mask and the point of minimum light transmission is located. CORAVEL, which is designed to work at the Cassegrain focus, is a fairly compact apparatus with a collimator focal length of only 60 cm. Nevertheless, its echelle grating which is used between the 43rd and 62nd orders gives a mean dispersion of about 2 Å/mm over the 1500 Å spectral range. The total light transmitted by the mask is measured by a photomultiplier. Rapid scanning at about 4 Hz is used to eliminate atmospheric scintillation effects and the correlation function is built up on-line by integration in the memory of the HP 2100 computer. The zero point of the radial velocities is determined by means of a hollow cathode iron lamp which illuminates the entry slit at the beginning and end of each measurement. The reduction of the Earth's motion is immediately done at the end of the measurement.

The mask used in CORAVEL is derived from the spectrum of Arcturus and consists of about 3,000 holes distributed over the 20 orders of the echelle grating. The useful zone of the mask is approximatively 13 x 70 mm. The calibration of the focal surface and the drawing of the work was done using the OPTRONICS two-coordinate microphotometer of the ESO Sky Atlas Laboratory. A small modification of the microphotometer allows it to be used in play-back mode to make a negative on a high-resolution photographic plate. A negative copy of this plate gives us the mask which in fact is a glass plate coated with chrome.

Measurements of the sky light from the laboratory permit a partial test of the mask. The correlation dip for the Sun is characterized by a 15 km/s width at half depth. The daily variation of the solar radial velocity (0.3 km/s at Geneva) is easily measured with a scatter of ± 0.1 km/s for the individual measurements. Tests on stars other than the Sun are planned during the next few weeks and will be the subject of another report.

An observation period at La Silla is planned after some months of observing in the northern hemisphere.

Of Apollos and Trojans

It is often seen in science that more is learned from abnormal ("pathological") cases than from the normal ones. This is certainly true in astronomy too.

The title of this note should not confuse the reader. We do not attempt to discuss the mentality or health of ancient Greek gods and warriors, but rather to summarize some new information pertaining to these two "families" of minor planets which has recently become available from observations with ESO telescopes. They represent extremes in the asteroid world: the Apollo planets are those which come closest to the Earth; the Trojans are more distant than any other known minor planets.

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Comparatively few Apollo asteroids are known to date. The most famous, (1566) Icarus, comes within 28 million kilometres from the Sun, in a very elongated orbit that also carries it across the Earth's orbit. The interest in these rare ob-