Minutes of the Ordinary General Meeting of the Cape Centre of the Astronomical Society of Southern Africa held at the Observatory, Cape Town on Wednesday 13th March, ~~at~~ 1974

In the absence of the chairman Mr Molyneux, Mr Turk opened the meeting at 8p.m and welcomed the 38 people present.

Apologies were received from Mr Molyneux, Mr Helps.

The acting chairman welcomed Mr Overbeek from Transvaal Centre.

The minutes of the last meeting were read and confirmed by Messers Larmuth and Lawton.

Matters Arising from the Minutes

Mr Larmuth reported that nine Saturday afternoons had been spent by the working team on the Ron Atkins dome and that a further three more Saturdays should see the job complete. The group would then turn its attention to the re-designing of the telescope optics.

Mr Turk reported that the ash trays had re-appeared.

The Acting-chairman then went on to announce details of the extra mural course of lectures to be delivered for the interested layman ~~at~~ by U.C.T's Prof. B. Warner. An up-to-date review of the Solar System would be provided in Beattie Building, Room 115 on Wednesdays at 8p.m. commencing 27th March, for R15.

Prof. Cillier's course of lectures, also on Wednesday evenings at the Cape Technical College reviews the development of astronomy from Copernicus to Quasars and Black Holes.

At this stage no definite speaker had been arranged for the next monthly meeting, but members would be notified shortly by post. Probably the next meeting would be on Tuesday 9th April so that the meeting would not clash with the programs of lectures being given by the two lecturers. The Committee, however, would make the final decision.

Mr Hurley announced that the April visitors night would be on the fourth Saturday of March to avoid the Easter Saturday in April. Mr Harding would inform the Visitor's Bureau of this change.

Mr Hurley strongly recommended Prof. Warner's set of 20 lectures to members of the Society. He expressed regret at the clash because Prof. Cilliers, who was also a member of the Society, was also a very good speaker.

The Acting-chairman then introduced the

the evening's guest speaker who was Prof. Brian Warner himself who spoke on "What It is Possible to Deduce from the Spectra of Stars".

[signature] 9.4.74

- A summary of the address given by Professor Brian Warner to the Cape Centre of the Astronomical Society of Southern Africa on March 13th, 1974.

Examples of the properties of stars that can be determined are temperature, amount of turbulence in the atmosphere, the elements present and their percentage, the period of rotation of stars, their magnetic fields, differential rotation (they are not like solid bodies, so different parts of them rotate with different speeds), and so on.

Prof. Warner began by discussing a slide of the solar spectrum made with a 13-foot spectrograph using a high dispersion grating. Although this typical photograph was black and white, it should not be forgotten that such spectra are coloured. A spectrograph sorts out the wavelenghts of light received. If all wavelengths are received, then we get a continuous spectrum. Dark lines mean that we are receiving no light from the sun at that particular wavelength or frequency.

It should be noted that the lines are not entirely black. A residual intensity occurs which means a reduction in light. In the atmoshere of the sun, therefore, there is something preventing light from getting out : atoms and molecules in the atmosphere of the sun. This is a result of the properties of atoms and molecules which cause a discrete absorption.

The next slide explained this. It showed the energy levels for an electron in the hydrogen atom : the Lyman series, Balmer series, etc. Differences between energy levels are measured in electron volts. For one particular jump of, for example, 10,15 eV, the electron cannot have any energy in between. It can absorb a photon of light of intensity 10,15 eV as a result of which one observes a line in the spectrum. Atoms therefore absorb only very discrete energies. When an atom loses energy the converse occurs and the electron drops back to a discrete inner orbit emitting a photon of radiation of intensity 10,15 eV.

The next slide showed what happens when a spectrum is photographed and run through a microdensitometer. The black lines were seen to have a definite shape in intensity and width rather than being uniformly black and infinitessimally narrow. This lecture, then, is more a discussion of the properties of atoms rather than of stars.

We can measure the positions of these lines, and this gives us the wavelenghts of the light absorbed in Å or in nanometres today. Now with few exceptions the wavelength of a line is uniquely assigned to a particular element, so by comparing stellar wavelengths with wavelenghts produced in the laboratory (e.g. using pure carbon electrodes), we can identify elements pres ent in stars. This technique results in a composition analysis of elements in a star. Much of this work was performed at the end of last century, especially by Lockyer. In this way helium was first discovered on the sun before it was found on earth being emitted by some rocks. Of the 92 ordinary elements found on earth, 67 are found in the sun by earth-based instruments. Other elements, naturally radioactive, would therefore have long since decayed on account of the age of the sun, or are very rare, or have their spectra in the far ultra violet. Rockets above the earth's absorbing atmosphere have detected the presence of these.

The second thing that can be duduced from the spectra of stars is the presence of isotopes of elements.

The next slide showed molecular bands - enormous numbers of lines virtually on top of each other. This was a slide of the spectrum of a C_2 molecule. Normal absorption lines occured due to common carbon, C_{12}. A molecule composed of one atom of C_{12} and one atom of C_{13} yielded another band. Further over on the slide could be seen another band characteristic of the C_{13}-C_{13} molecule. A 10Å shift for these isotopes could be seen, which is considerable.

In some stars the isotopic composition is unusual. This gives us a clue as to what has been going on in stars during the course of their lives.

The third property that can be found from a study of the spectrum of a star is the radial velocity of the star. When the wavelength of a line is measured, allowance must be made for the Doppler effect. Addition of the radial velocity of the star thus determined to the transverse motion (determined by astrometry) gives the full motion of the star. In fact the structure of our whole galaxy has been determined as a result of repeated measurements of Doppler shifts.

Many stars have variable radial velocities such as the Cepeid variables. These changes can be measured.

Also we can measure the radial velocities of double stars (unless we have a polar view of the binary). A knowledge of this leads to the determination of the mass ratio of the pair. If the binary is eclipsing we can then calculate the masses of the two stars. Proof that stars rotate is also found by studying the radial velocity of a double star during eclipse : a clearly defined up and down kink is seen in the falling light curve of the binary as first the approaching and then the receding limbs of the eclipsed star are blotted out.

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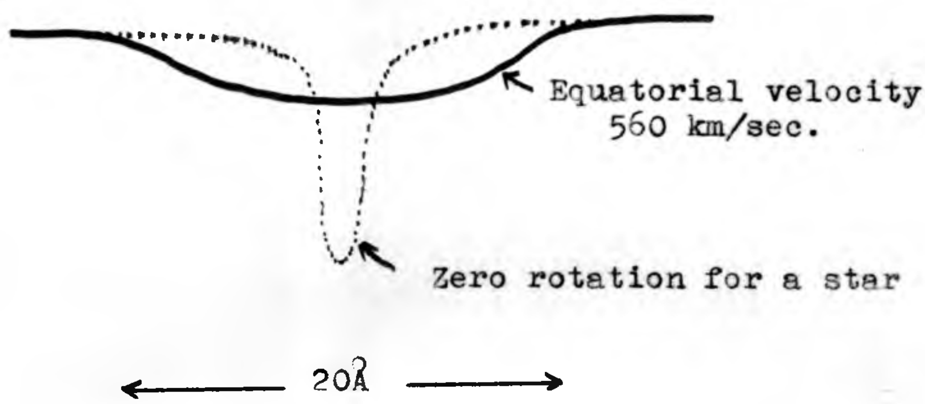
If stars are rotating we should see a distortion of the spectrum lines themselves. After all, we see light from all parts of the sun, so one limb shuld be blue-shifted and the other limb red-shifted. Thus each line in the spectrum should be "smeared", the extent of smearing or broadening of the lines being determined by the rate of spin of the sun or other star.

It is possible to calculate the extent of smearing, i.e. the profile of the spectral lines. For a star with zero rotation the lines will as in the dotted case below, while a star with an equatorial velocity of 560 km/sec will be wide and shallow with a width of about 20Å :-



Thus if we find a star with lines of this width, we can be fairly sure it is rotating at 560 km/sec. This assumes the star is spherical. This, however, is a bad assumption for at a speed of 500 km/sec. the star would be maximally flattened and almost flying apart. It also assumes a non-darkened star. Our sun, for example, is limb-darkened, so there won't be as much light from it and this complication must be taken into account.

A further complication is that if you have a rotating star the gravity can be almost zero at the equator and very great at the poles. Now the amount of light emitted depends on gravity. The star will be emitting light from the poles and will be almost dark at the equator where there is little gravity, according to theory.

To complicate the problem even more, the sun is not rotating like a solid body - the polar regions rotate more slowly : 2 km/sec on the sun's surface, which is pretty slow. Some stars have a rotation speed of 400 km/sec. Our sun has an equatorial rotation period of 28 days compared with 32 days at the poles. A good deal of this differential rotation effect is suspected on other stars. Its effect can be compared to the effect of the Coriolis force experienced by the earth's and by Jupiter's atmospheres.

Recently attempts have been made to measure this effect using the above mentioned spectroscopic technique. Spectral profiles have been computed for different amounts of differential rotation, and this effect may be even more important than the effect on line profile due to gravity darkening. The effect is to apparently deepen the profile at the centre (i.e. to make it even darker) yet make it shallower at its two boundaries.

Another feature that can be determined from the spectrum of a star is the presence of a magnetic field. Our knowledge of this relies on understanding the Zeeman effect on atoms in a magnetic field. Suppose we examine the central spectrum of rhodium emission lines (produced in the laboratory be heating the element rhodium in an   arc). The spectral lines are split by a magnetic field, the amount of splitting being proportional to the strength of the magnetic field applied or present (provided the magnetic field is not too strong.)

Using a Zeeman analyser in 1950, Babcock of Mount Wilson found that some stars do, in fact, possess magnetic fields. The splitting, though, was very small.

The indirect means of determining the Zeeman effect employed left and right hand circular polarization.

More recently stars have been discovered with very strong magnetic fields, e.g. 30 000 gauss, so the Zeeman effect has been clearly observed. Compare this figure with the value of the strength of the earth's and sun's magnetic fields : 1 gauss ! In sunspots, though, magnetic fields of 1000 gauss are known. Most A-type stars have large magnetic fields, e.g. in the spectrum of β Corona Borealis the Cr II line is split into two components, the Fe III line has three components, and so on. The magnetic field strength is about 16000 gauss.

If the magnetic field of a star is not coherent a set of smeared spectral lines will result. The earth has a well-ordered dipole field, and so have some stars. All magnetic fields of stars are variable. Some vary regularly, e.g. from 7000 gauss to -60 000 gauss (minus means to south pole pointing upwards). This is due to the rotation of stars. As on earth, magnetic N and S does not correspond with polar N and S. Often on stars the N and S mangetic poles lie on the equators of the stars, so we see attenuation as the star rotates.

Consider now a different line of thought. The width of solar spectral lines is about a tenth of an Angstom unit. Why is this so? The atmosphere of a star is hot. Classically an atom may absorb or emit at one wavelength, but because of the uncertainty principle this is smeared slightly. But because the stars are hot, atoms are in motion. This means that at any instant some atoms are travelling towards us so absorb blue light; others are travelling away and absorb redder light. Absorption thus occurs over a slightly wider range of the spectrum for a given wavelength. If the atmosphere is turbulent more smear will be the result. It is possible, in fact, to sort out thermal Doppler effects from the turbulence.

Now consider again the possible profiles of stellar spectral lines. Why are some lines in stars extremely broad? If the density of atoms in a star increases, more absorption of light occurs. However, you can't go blacker than black, so when all the light is absorbed, the bottom of the profile is reached (in the centre of the profile, of course). But for high speed atoms to the left and right of centre, the wings of the profile begin to darken. We now have a quantitative way of measuring the density of atoms in stars once the darkening effects, etc. have been taken out.

Now if the atmosphere of a star is dense, there are collisions. If it absorbs light at this stage the energy wavelength is changed in the process. This therefore produces broader lines. This is called the luminosity effect in stars. For example, a super-giant has very sharp lines, the extent of their width being due to lesser effects such as turbulence and other Doppler effects. The dwarf star Alpha Gemini has very broad lines. Some dwarfs have lines in their spectra as much as 100Å wide. Measurement of the width of these lines gives a measure of the pressure and hence the gravity in a star, as pressure is proportional to gravity.

Further work involves high resolution studies of stellar spectra, and these are yielding information on the coronas of stars.

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Mr Hurly suitably thanked the guest speaker for an outstanding address.