Variable Star Section Meeting

held at the Institute of Astronomy, Cambridge, on 1994 February 19

A one-day meeting on the subject of Variable Stars was hosted by the Cambridge University Astronomical Society on Saturday 1994 February 19. This was one in the series of popular meetings organised jointly by CUAS and the BAA Sections. The venue was the Hoyle Building at the Institute of Astronomy, and about 80 people attended.

A history of variable star astronomy

The first speaker was Dr Allan Chapman who gave a history of variable star astronomy from about 1600 to the 1920s. He explained that, for most of this time, variable stars were viewed as a minor puzzle on the edge of astronomy, but in the early years of this century their significance increased when they were used to give answers to some of the central problems of the science.

The supernova of 1572 was the first variable star widely to be recognised as such in the West. It made Tycho Brahe into an astronomer and his observations of it dealt a severe blow to the Aristotelean view of the universe. In 1596, David Fabricius discovered Mira which, at first, was thought to be a nova but was later found to have reappeared. In the 1670s it was realised that its variations were periodic. By the middle of the 18th century about half a dozen variable stars were known. These could be divided into two types: those which flared up suddenly and then faded away again, disappearing for good (the 'flashers') and those in which the variations recur in some form or another (the 'winkers'). In 1782 John Goodricke discovered the periodicity in the variations of Algol and proposed a model in which the visible star was being periodically eclipsed by a dim star orbiting it. Unfortunately, this model was not widely accepted. William Herschel was against it because he was unable to see the dim companion with his 20-foot telescope ('Astronomy is about seeing things'). Another reason for the rejection of the eclipsing binary model was that it could not be generalised to explain the variations of other stars such as Delta Cephei. The Newtonian style was to go for universal explanations and, at that time, the eclipsing binary model would have seemed rather ad-hoc.

In the early 19th Century, more and more variable stars were being discovered. Argelander suggested that observing them would be good work for amateurs as most professional astronomers were too busy with routine positional work. In the meantime, binary star models were becoming more popular. In 1842 Bessel predicted the existence of a companion to Sirius which was later found by Alvan Clark. However, it wasn't until 1889, when advances in photography and spectroscopy allowed Voegel to detect the periodic shift in the spectral lines of Algol, that the eclipsing binary model was confirmed and became widely accepted.

In the early 20th century variable stars started to become useful in astronomy. The key event in bringing this about was Henrietta Leavitt's discovery of the Cepheid period–luminosity law in 1912. This offered the possibility of determining the scale of the universe for the first time. However, in order to do this, the zero-point of the period–luminosity law had to be determined and, unfortunately, not even a single Cepheid was close enough for its distance to be known. Harlow Shapley set about trying to find the luminosity of galactic Cepheids statistically from their proper motions. He used the values he got to measure the distances of globular clusters. From these results, and the distribution of these clusters over the sky, he proposed that the Galaxy had a diameter of 300,000 light-years (LY) and its centre lay 50,000LY in the direction of Sagittarius. There still remained the question of whether our Galaxy was the whole of the universe. It was not clear whether objects like M31 were within our Galaxy or else were separate galaxies in their own right. This was sorted out in 1924 when Edwin Hubble found a Cepheid in M31 and was able to derive a distance of 750,000LY, placing it well outside our own Galaxy.

Observing IP Pegasi

Following Dr Chapman, Bill Worraker gave a short description of an observing campaign he is coordinating this autumn on the dwarf nova IP Pegasi. This star normally varies between mags 12.0 and 15.5 with a mean outburst interval of 95 days. However, it also shows eclipses with a period of 3h 46m. Out of outburst these are about 3 mags deep and last about 42 minutes but during outburst they are still well over a magnitude deep. Bob explained that the aim of the campaign was to gather good quality timing and photometric data on these eclipses during an outburst. A secondary aim was to demonstrate the coordination of visual and CCD observations of such eclipses. He suggested that all observers interested in taking part should start monitoring the field of IP Peg as soon as possible, so as to become familiar with the comparison stars. When an outburst was detected an alert would be put out and predictions for the eclipses would be issued. The outbursts only last about a week and each observer should attempt to cover one complete eclipse on each clear night. Magnitude estimates should be made at 1 minute intervals and any results should be sent in to him for analysis and possible publication.

The SPA VSS programme

The last speaker of the morning was Tony Markham, the Director of the Variable Star Section of the Society for Popular Astronomy (SPA) – the new name for the Junior Astronomical Society. He said that in the past the JAS VSS programme had mainly consisted of naked-eye variables because it was thought that these were easier to observe than fainter stars. However, it can be difficult to find suitable comparison stars for naked-eye variables, atmospheric absorption can be a problem, and there are so few naked-eye variables anyway. Tony had decided to add several binocular stars to the programme. These included RZ Cassiopeiae, 68u Herculis and seven Mira stars. The Mira stars can only be observed when near maximum but they were proving very popular with the members because of their large, bold variations. Tony went on to show light-curves of many of the stars on the SPA VSS programme. He pointed out the presence of large systematic differences between observers in the light-curve of Beta Pegasi. He also mentioned that the light-curve of Alpha Orionis showed the star to be faint each August. This was probably due to the influence of atmospheric absorption as the star can only be observed at low altitude at that time of year.

Statistical analysis of cataclysmic variables

After an excellent buffet lunch laid on by CUAS, the afternoon session was opened by Dr Martin Hendry of Sussex University. Dr Hendry is part of a group at Sussex which includes Robert Smith, Sandi Catalan and Martin Still who are working on the statistical analysis of observations of cataclysmic variables (CVs, also known as dwarf novae). He explained that he was not a true variable star researcher but was really a theoretical cosmologist, who had become interested in CVs when he found that he could apply the same statistical techniques to them that he had been using to analyse galaxy redshift surveys.

Dr Hendry briefly described what CVs are (stars which undergo explosive outbursts quasi-periodically on timescales of tens to hundreds of days) and how they can be classified on the basis of their light-curves (into U Gem, SU UMa and Z Cam types) or on the basis of spectroscopic observations of their magnetic field (into 'polars' and 'intermediate polars'). He also outlined the current binary model for CVs which involves one of the components being a compact object (white dwarf) surrounded by an accretion disc built up from material drawn off from the other component.

Light-curve studies can be divided into two types. In the first, the properties of each star are averaged over a long time interval and the results for various stars compared. This sort of study has revealed, for example, a relationship between the mean period and the mean amplitude similar to that for recurrent novae. The second type of study analyses how the properties change with time within the light-curve of an individual star. Only through this type of study can we hope to understand the underlying mechanisms of the outbursts.

Dr Hendry went on to describe how the Sussex group abstracted the details of a CV light-curve by measuring 3 parameters for each outburst cycle: 'tb', the time in burst; 'tq' the time in quiescence, and 'tp', the period. There were two questions that they were trying to answer in this work: 'is there any evidence for chaotic behaviour in the light-curves?' and 'is there any evidence for correlations between tb and tq?'. The first question is important because the physical mechanisms causing the outbursts are thought to be inherently non-linear, which would lead one to expect them to exhibit chaotic behaviour. One way to look for such behaviour is to plot a 'return map': for example tb for each cycle can be plotted against tb for the previous cycle. If the behaviour is chaotic then the points will fall on a distinct curve rather than be scattered at random. Dr Hendry showed such return maps for KT and FO Persei. These showed too much scatter to be purely chaotic and he suggested that they may be the result of a mixture of chaotic and quasi-periodic behaviour.

The second question, the existence of correlations between tb and tq, is important because it may allow us to distinguish between the two proposed mechanisms for CV outbursts. One mechanism has the outbursts resulting from changes in the rate of flow of material into the disc. This mechanism would suggest that long outbursts (large tb's) should be followed by long quiescent intervals (large tq's), as the source of the material would be expected to take longer to be replenished. The other mechanism has the outbursts resulting from changes in the viscosity of the material within the disc. In this case one would expect the length of the outburst to correlate with the length of the preceding quiescent interval, as the longer outbursts would require a longer time for the viscosity to build up. Attempts have been made before to distinguish between these two mechanisms on the basis of visual observations (e.g. Reference 1) but the results have been inconclusive.

An analysis of BAA VSS data by the Sussex group was similarly inconclusive, however, they had gone one step further and turned the problem round: assuming that a correlation does exist, then would we expect it to be detectable with the observations we have available? Could it be that the observations are just not accurate enough to allow us to distinguish between the two models? To investigate this they had made up sets of simulated observations. The resulting synthetic observations were analysed using the same techniques as had been used on the real observations to see how well the correlations could be recovered.

They found that there is a strong tendency to underestimate the correlations and that this tendency increases sharply as the correlation gets weaker. However, Dr Hendry said that if the correlations between tb and tq are good then we should still be able to detect them with the available visual observations. However, correlations involving the amplitudes of the outbursts tend to become washed out if the observational errors are greater than 0.1 mag. This suggests that we might need to use CCDs and take means of large numbers of observations from each night in order to detect these.

Dr Hendry finished by saying that the Sussex group hope to investigate various other areas using this simulated data method, including the effects of observer bias and misidentification on the correlations, how the above results apply to SU UMa stars (which show occasional super-outbursts), and the effects of 'filling in' gaps in the data. Another area is how the relative proportions of chaotic and periodic behaviour affect the return map.

Red supergiant variables in the Double Cluster

The next talk was given by Tristram Brelstaff, the VSS Director, and was entitled 'The red supergiant variables in the Double Cluster'.

The presence of red stars in the Perseus Double Cluster had been commented on by several observers in the 19th Century but the definitive visual study was carried out by the Reverend Thomas Espin in 1891–92. He identified nine red stars using a visual spectroscope attached to his 17-inch reflector. At the time, these were not recognised as supergiant stars. It was not until the work of Antonia Maury (published in 1897), who identified a set of stars with unusually narrow spectral lines, and Eijnar Hertzsprung (1905), who showed that these stars were unusually distant, that supergiants were recognised as a distinct class of stars. In 1926, a spectroscopic survey carried out at Mount Wilson by Walter Adams and co-workers showed that seven of Espin's red stars had radial velocities and proper motions that were consistent with their being members of the Double Cluster. During the 1940s and 1950s, further spectroscopic studies by Philip Keenan, William Bidelman and Victor Blanco increased the number of known and suspected members to 17 and seven, respectively. Keenan commented on the fact that several of these stars, while obviously associated with the Cluster, were up to 5 degrees away from it, well outside of the accepted bounds of the Cluster. They are now thought to be members of the association of luminous stars, known as Perseus OB1, that surrounds the Double Cluster.

In the 1960s, there was an increase in interest in the Double Cluster red supergiants when they were used to test various theories and models of stellar evolution. They were particularly suitable for this because they were by far the largest grouping of red supergiants in our Galaxy for which the distance was relatively well-determined.

In 1969, in a study of red supergiants in general, but which relied heavily on the Double Cluster ones, Richard Stothers used the ratio of blue supergiants to red supergiants in an attempt to test the existence of certain sub-atomic reactions in nature. Hayashi had found that the inclusion of certain neutrino interactions in his evolutionary models led to the stars spending very little time in the red supergiant phase. The fact that there were nearly equal numbers of blue and red supergiants in the Double Cluster (and Perseus OB1) seemed to suggest that these interactions could not be taking place. However, later studies showed that stars can stay in the red supergiant phase for quite a long time while they are burning helium. It is only in the post-helium burning phases that the neutrino processes speed up the evolution and, ultimately, take over altogether in a supernova explosion.

Tristram went on to show the light-curves for those Double Cluster red supergiants that have been under observation by the BAA VSS. In the years 1920–91, S Persei had undergone large-amplitude semiregular variations with a period of around 820 days. Observations of the other stars (RS, SU, AD, BU, KK and PR Persei) only go back to around 1970 and their variations are small in amplitude. However, some of them appear to show two periods simultaneously: a short one of a few hundred days and a longer one of one to two thousand days. Tristram hopes to publish a more detailed account of this material in the BAA *Journal* at a later date.

Finding variable stars

The final speaker of the day was Mike Collins, whose subject was 'Finding variable stars on patrol plates – opportunities and responsibilities'. For several years now, Mike has been using twin 135mm telephoto lenses to photograph the northern Milky Way as part of the UK Nova Patrol. Originally, his aim was to look for faint novae but he has had no success in this direction so far. However, during this search he has come across many suspicious objects, each of which he had to check out. Out of a total of 730 such objects, 479 turned out to be known variable stars, 110 were minor planets (the faintest was at magnitude 11.6 when detected) and 141 were previously unknown or else only suspected variables. Most of the new and suspected variables have turned out to be pulsating red giants (Mira stars and semiregular variables).

One of the responsibilities of the discoverer of a new variable star is to determine the period of its variation, if it has one. Mike uses the method of least squares to find the values for the epoch of maximum and period that best fit his observations. He described this process as trying to find the lowest point of a surface shaped like a cow's udder. The trick is to make sure that you go down to the lowest 'teat' rather than one of the higher ones. Mike stressed the importance of giving estimated errors for derived values as this gives other people an idea of how accurate your results are and how long into the future they can be expected to give reliable predictions.

The discoverer of a new variable star also has the opportunity of giving it a temporary designation that will be used until the editors of the *General Catalogue of Variable Stars* get round to giving it an official name. Mike reviewed some of the methods of forming such temporary designations. In *The Astronomer* magazine the names are given by Guy Hurst and are based on the star's celestial coordinates. The prefix 'TASV' ('*The Astronomer* Suspected Variable') was used to indicate that the discoverer had not quite managed to convince Guy that the star was variable. Another naming method was to use the discoverer's initials followed by a serial number. 'DHK15' is the 15th variable star discovered by Daniel H Kaiser, an American carrying out a sky patrol very similar to Mike's.

It would be nice to have more visual observers looking at these stars. They tend to be slightly unpredictable so that after a few years their cycles often get out of step with the published data. They are like badly behaved geriatrics (red supergiants are old stars) that need social workers (visual observers) to keep an eye on them.

Everyone seemed to agree that the meeting had been a great success. Most of the credit for this should go to the meeting organiser, Paul McLaughlin, and his CUAS helpers.

Tristram Brelstaff, *Section Director*

1 Cannizo, J. K. & Mattei, J. A., *Astrophys. J.*, **401**(2), 642–653 (1992)