AAVSO PHOTOELECTRIC PHOTOMETRY NEWSLETTER

Volume 22, Number 2; December 2003

Editor: John R. Percy

Contributions to this *Newsletter* are gratefully received at any time. Please send them to: John Percy, Erindale Campus, University of Toronto, Mississauga ON, Canada L5L 1C6; e-mail: jpercy@erin.utoronto.ca All material has been written by the Editor, unless otherwise indicated.

Apologies

Apologies from the Editor for the lateness of this issue. It has been a busy autumn. For those of us in the colleges and universities in Ontario, Canada, this has been the year of the "double cohort". Until four years ago, we had a K-13 school system; there was a grade 13 in high school. That grade was finally eliminated and, if you think about it carefully, you will realize that this means two graduating years from high school arrive at the colleges and universities in the same year – and with two different curricula. Having just marked my "Astro 101" exams, I can say that this class did very well.

Another big project was the launching of the Canadian astronomy education website. It's aimed at teachers and other educators, but there is material for students, amateur and professional astronomers, and the public. There's even a Canadian Junior Astronomer Program. You can check it out at:

http://www.cascaeducation.ca

Yet another big project was editing the proceedings of a Special Session on "Effective Teaching and Learning of Astronomy", held as part of the 2003 International Astronomical Union General Assembly. The emphasis was on K-12 education because (1) that is the level at which most people learn astronomy, and (2) that is the level at which teachers usually have little or no training in astronomy, or astronomy teaching. Jay Pasachoff (Williams College) and I are editing a short version for the IAU and a full version for Cambridge University Press.

But that's still no excuse!

IAU Colloquium 193

Every two years, astronomers interested in pulsating variable stars meet to discuss new results and new problems, usually with the sponsorship of the International Astronomical Union (IAU). The 2003 pulsation meeting was in Christchurch, New Zealand, in July, and was IAU Colloquium #193.

When I arrived in Auckland NZ from warm and humid Toronto, the weather was not auspicious. It was precipitating and below freezing on the South Island (where Christchurch is located), and Duneden Airport (south of Christchurch) was actually closed. But after a hair-raising stop in Windy Wellington, my plane arrived safely in Christchurch. The next day was a day of rest and equilibration, when I could rediscover some of my favourite places in Christchurch; I had two previous lengthy visits to this beautiful city. But I had to tread carefully: there was ice on the sidewalks; for better or worse, New Zealand has not adopted the use of road salt.

That evening, the conference began with a reception, featuring the singing, chanting, and dancing of a Maori youth group – an excellent, enthusiastic performance, at least as good as any of the performances which I had encountered as a tourist. The conference excursion (much to my pleasure) was a winery tour of the Christchurch area; the production of fine wines (especially whites) has really caught on in the last two decades, just as it has in the Niagara region of Ontario, Canada. The conference banquet was in a very special venue: the Antarctic Centre, adjacent to Christchurch Airport, which is the starting point for many flights to Antarctica. This modern Centre has excellent multi-media presentations about all aspects of the frozen continent. It's a good complement to the downtown Christchurch Museum which has a comprehensive collection of historical artifacts related to Antarctic exploration. The "star" of the banquet was the young daughter of Conny Aerts (University of Leuven). Conny hosted the 2001 pulsation conference in Leuven, Belgium, and is the incoming President of the IAU Commission on Variable Stars. Her daughter provided a droll commentary on an astronomers' conference as seen from a young person's eyes. There were some interesting comparisons with statisticians; Conny's husband is one of those. In addition to these formal events, there were numerous informal gatherings – especially in the University pub.

The theme of the conference was "Variable Stars in the Local Group" (of galaxies). There were dozens of interesting papers on all kinds of pulsating stars, but the ones of most interest to me were the ones on pulsating red giants. Using AAVSO photoelectric data, and data from robotic telescopes, my students and I have been studying bright pulsating red giants. We have been able to identify their pulsation "modes" – in-and-out pulsations in the fundamental, first, second, and third overtones. Some stars pulsate in two or three modes simultaneously. The amplitudes of the modes rise and fall on a time scale of thousands of days. These are all new discoveries which are made possible by the unique long-term photometry which the AAVSO can collect.

Laszlo Kiss and Tim Bedding (U. Sydney) have discovered thousands of pulsating red giants among the *giant branch* (GB) stars in the LMC. Previously discovered pulsating red giants have been primarily *asymptotic giant branch* (AGB) stars. GB stars are fusing hydrogen into helium in their interior, as they become red giants for the first time. AGB stars are fusing helium into carbon in their interior, as they become red giants for the second time. Kiss and Bedding used photometric data from the OGLE-II survey. They reprocessed the data, however, to achieve precision of better than a hundredth of a magnitude – even for the faintest LMC stars. They were able to identify pulsating red giants with amplitudes of only 0.01-0.02 magnitude! They found that the GB stars tended to have the smaller amplitudes and pulsate in higher overtones, whereas the AGB stars have larger amplitudes and pulsate in lower overtones. Incidentally, Laszlo Kiss may be known to AAVSO-ers for his work with the Variable Star Section of the Hungarian Astronomical Association. He is now a post-doctoral fellow, working with Tim Bedding, in Sydney.

Another impressive result was the discovery and study (by M. Rejkuba, D. Minniti, D.R. Silva, and T.R. Bedding) of pulsating red giant variables in the galaxy NGC 5128, which is outside our Local Group of galaxies. NGC 5128 contains the radio source Centaurus A, and is the nearest radio galaxy to us. By comparing the period – K magnitude relation in this galaxy with the same relation in the LMC, they were able to determine the distance of NGC 5128 to be 4.2 ± 0.6 million parsecs. So pulsating red giants can be used for distance determination.

Yet another interesting project (by T. Lebzelter, P. Wood, K.H. Hinkle, R. Joyce, and F. Fekel) was the study of pulsating red giants in globular clusters. Globular clusters have been studied for variable stars for over a century, but those variables tend to be RR Lyrae stars with periods less than a day. These variables have been studied especially by my late colleague Helen Sawyer Hogg here at the University of Toronto, and by her student, my present colleague Christine Clement. They typically observe clusters for 1-3 weeks, and use the images to determine the periods and amplitudes of the RR Lyrae stars. It is difficult to study the pulsating red giants because they have periods of tens to hundreds of days, and very few observers – until now – carry out systematic long-term imaging of globular clusters. Incidentally, this would be an interesting and appropriate project for skilled amateur CCD observers. Pulsating red giants in globular clusters appear to have similar properties to their counterparts in the field; they can pulsate in one of several modes, and some have mysterious "long secondary periods".

A continuing mystery is the *long secondary periods* which occur in about a third of all pulsating red giants – including those on the AAVSO PEP program. Peter Wood (Mt. Stromlo) has explored all possible explanations for these long periods, and concluded that "At the present time, there is clearly no satisfactory explanation for the long secondary periods in red semi-regular variables. To our knowledge, these are the only large amplitude (semi)-periodic stellar variations which are currently unexplained." Possible explanations include: eccentric motion of a low-mass orbiting companion, radial or non-radial pulsation, rotation of an ellipsoidal red giant, episodic dust ejection, star spot cycles, or some new mode of stellar pulsation. There are severe difficulties with each of these models.

Pulsating Red Giants in Symbiotic Binary Stars?

Symbiotic binary stars have two components – one cool, and one hot. The cool component is usually a red giant star. The hot component may be a hot main sequence star, or a compact object (white dwarf, neutron star, or black hole) with a hot accretion disc around it.

If a symbiotic binary star has a red giant component, then that component should be a pulsating red giant. Several symbiotic binary stars have M giant components whose pulsation periods should be 30-100 days, based on our study of bright pulsating M giants with similar spectral types.

My student Ashley Harrett has begun to look at some of these systems, using visual data. In the three stars examined so far (CH Cyg, CI Cyg, Z And), there is no sign of a period in the 30-100 day range, but there is a period in the 300-1000 day range, which may correspond with the "long secondary periods" discussed above.

We now plan to look at photoelectric data, such as the AAVSO PEP data on CH Cyg, to see if the shorter-period variations are perhaps too small to be seen in the visual data. So keep the PEP observations coming!

Why Are "Multiperiodic" Pulsating Stars Important?

Astrophysical information is difficult to obtain. Astronomers would like to know the mass, radius, luminosity, temperature, and composition of stars, as well as many less obvious properties. But masses are available only for a small number of stars which are members of simple, well-observed binary systems. Radii are difficult to measure for light sources which appear as points! Luminosities can be determined if the distance of the star is known; this is now true for tens of thousands of stars (thanks especially to the *Hipparcos* satellite), but not for many interesting and rare classes of stars. For stars which pulsate, the *period* can be determined, almost always to a high degree of accuracy. For stars which pulsate in two or more different modes, an additional two or more periods can be determined. There are many ways in which these unique pieces of information can be used. For the Cepheids, for instance, the period is a function of the luminosity of the star,, and this relation can be calibrated to produce the famous *period-luminosity relation*.

If two periods are known, they can be compared with the periods predicted by "models" or simulations of stellar structure. One way of doing this is through the *Petersen diagram* – a graph of period ratio versus period. The longest observed period, and the ratio of the observed periods, are compared with predictions for model stars with specified mass and radius, to see what mass and radius agree best with the observations. This has been done successfully for "double-mode" Cepheids and RR Lyrae stars.

If more than two periods are observed, there are even more possibilities. Other characteristics of the models can be checked. In the case of the sun, in which hundreds of pulsation modes are observed, it is possible to check almost every aspect of the internal structure, including the rotation. In the near future, especially by using satellites such as *MOST*, mentioned below, it should be possible to do this for thousands of other pulsating stars. The age of *asteroseismology* has begun.

News about Be Stars

Be stars are hot B-type stars which have shown emission lines in their spectra on at least one occasion. The emission arises from a disc of gas ejected from the equatorial regions of the star. As the definition suggests, the Be phenomenon is variable; the disc (and therefore the emission lines) can appear and then dissipate. There is no clear explanation of why this happens. There are several bright Be stars on the AAVSO PEP program. One of the purposes is to monitor the development of a disc by observing the resulting brightening of the disc (or fading, if the disc is seen edge-on and obscures the star). Those of us who observe and sstudy Be stars are very pleased that there is an on-line *Newsletter*, sponsored by the IAU Working Group on Active B Stars, to keep us up-to-date on the subject. We are grateful to Gerrie Peters (University of Southern California), David McDavid (University of Virginia), and Doug Gies (Georgia State University) who have maintained this service for so many years.

You can access the *Be Star Newsletter* on-line at:

http://www.astro.virginia.edu/~dam3ma/benews/

There is a particularly important recent article on the presence of non-radial pulsation in these stars. The "beating" of these modes may produce pulsations which are energetic enough to help to eject the disc. See the abstract at:

http://www.astro.virginia.edu/~dam3da/benews/volume37/abs37/rivi0.html

An excellent review article on Be stars has recently appeared in the *Publications of the Astronomical Society of the Pacific*, **115**, 1153 (2003). See the abstract at:

http://www.astro.virginia.edu/~dam3da/benews/volume37/abs37/porter0.html

For general information about Be stars: there is a useful article in the AAVSO's "Variable Star of the Month/Season" series at:

http://www.aavso.org/vstar/vsotm/1001.stm

RV Tauri Stars

RV Tauri stars are low-mass pulsating yellow supergiant stars which show alternating deep and shallow minima. The cause of this phenomenon is not known for sure, but my students and I are working on the hypothesis that it is due to the presence of two different pulsation modes, whose periods have a ratio close to 2:1. This causes the modes to reinforce and cancel every other cycle. Last year, undergraduate student Farisa Mohammed completed a project using visual photometry of nine stars: AG Aur, AV Cyg, SU Gem, AC Her, SX Her, TT Oph, UZ Oph, TX Per, and V Vul. Some of these stars are classified as RV Tauri stars, and others are classified as SRd variables, which are semi-regular, and do not show the alternating deep and shallow minima. We believe, however, that many RV Tau and SRd variables are mis-classified. Farisa's results support the notion that there is a "spectrum" of behaviour in low-mass pulsating yellow supergiants, from the reasonably periodic Population II Cepheids, through the RV Tauri stars, to the SRd variables.

Many of the supposedly semi-regular SRd stars turn out to be quite periodic. This opens up the possibility of detecting their evolution by the study of their period changes. This is the goal of Jaime Coffey's project, described below.

There are two RV Tauri stars in the AAVSO PEP Program: AC Her and U Mon.

What My Students Are Doing This Year

Once again this year, I have a group of keen undergraduate students, working on variable star research projects. Kaushala Bandara is studying the variability of R CrB stars at maximum light. R CrB stars are stars in an advanced stage of evolution, with large abundances of carbon, but – unlike normal stars – hardly any hydrogen. Suddenly and unpredictably, these stars fade by up to several magnitudes, then slowly return to maximum light. The fadings are believed to be due to clouds of gas and dust which are ejected from the star. If the clouds lie in the line of sight, then the light of the star will be blocked, and the star will fade.

A few R CrB stars, including R CrB itself, are known to pulsate, and the pulsation may play some role in causing the ejection of the clouds of gas and dust. Kaushala is analyzing the large body of on-line data on about a dozen R CrB stars.

Jaime Coffey is collecting data on SRd variables – low-mass yellow supergiant pulsating stars with periods of several tens of days, and semi-regular variations. Some have been observed for almost a century. She is gathering times of maximum light from the literature, and also measuring new times from recent on-line data. This will enable her to use the (O-C) method to look for evolutionary period changes in these stars. They are believed to be in a rather rapid stage of evolution, so the evolutionary period changes should be detectable.

Ashley Harrett's project was mentioned above. She is studying the pulsation of the red giants in symbiotic stars. If they are like single pulsating red giants, then they should have periods of a few tens of days. So far, in three stars, she has found no sign of such periods, only periods of a few hundred days. These are much more like the "long secondary periods" mentioned above.

Bhairavi Shankar is studying all available data on ρ Cas – one of the largest and most luminous "hyper-giants" in our galaxy. This star is in the AAVSO PEP Program. Its variability has been known for a century. It varies irregularly on time scales of hundreds of days. One of its “claims to fame” is episodes in which it ejects large amounts of mass; a year or two ago, it was losing mass at a rate greater than any known “normal” star. Are these mass-loss episodes triggered by pulsation? Bhairavi is looking at all available photometry – visual, photographic, photoelectric – to see how its pulsation period(s) and amplitude have varied with time, and whether the amplitude correlates with the mass loss.

These four students are undergraduates. But I also supervise one or two outstanding senior high school students through the University of Toronto Mentorship Program. This year’s students are Wojciech Gryc and Janice Wong. We have not yet finalized their research projects, but one interesting spin-off of their projects will be to identify links between the high school science and math curriculum, and the concepts which are used in variable star study and research. This could form the basis for variable star research projects by groups of high school students elsewhere – a sort of higher-level version of the AAVSO’s famous *Hands-On Astrophysics* project.

MOST is Launched!

MOSY – Microvariability and Oscillations of STars – is Canada’s first astronomical satellite. To my knowledge, it is the first satellite which was primarily devoted to the study of variable stars. It was launched in June, and has recently been providing good scientific data. Its merit is its precision; from space, it can measure to a precision of micro-magnitudes. It will observe a variety of small-amplitude pulsating stars, especially those with a complex mixture of pulsation modes which can be used for “asteroseismology”: the observed periods can be used to deduce the internal structure of stars.

MOST is about the size of a suitcase. It carries a 15 cm telescope. Its price tag is $7 million Canadian, or about $5 million US. It uses an innovative pointing system to keep the target star centered. Assuming that this technology continues to work well, it will represent an important Canadian contribution to space technology (says John Percy, a proud Canadian).

AAVSO IR Photometer Group Report

Doug West

The AAVSO IR Photometer Group currently has four observers; they are Dirk Terrell, Michael Koppelman, Jim Wood, and Doug West. As of 12 November 2003, the group had submitted 127 observations to the AAVSO database. The reporting method of the IR group is different from the visual PEP group in that the IR group reports their observations directly through the WebObs interface or one of the regular reporting methods of the AAVSO.

The group’s current emphasis is on observation of the eclipsing binary star Algol. The J and H band light curve for Algol hasn’t been observed in about 20 years. The Mira variables Omi Cet, R Leo, and W Ori are also prime targets. For example, a recent observation of the carbon star W Ori gave V=6.08, J=1.41, and H=0.37. The V band measurement was taken with a SSP-3. Note the large magnitude difference between V and H, which is typical for late type giant stars.

The SSP-4 is different from the SSP-3 in that the detector is thermoelectrically cooled to -40 C. The cooling cuts down on the thermal noise and gives a higher signal-to-noise ratio. Even with the cooling, the InGaAs detector in the SSP-4 isn't nearly as sensitive as the Silicon detector in the SSP-3. As a result of this lower sensitivity the SSP-4 with a 10" scope is limited to about 4th magnitude. With a clear filter, the instrument can detect down to 6th magnitude (effectively H band). This may sound like a really big limitation; however it doesn't turn out to be, given this limiting magnitude, there are still hundreds of objects to observe.

If you are interested in IR photometry please contact Doug West at dwest61506@aol.com.

What Use is AAVSO Photoelectric Photometry?

The first and foremost answer that I would give to this question is that the AAVSO Photoelectric Photometry Database is one of the longest of its kind. This kind of database is essential for understanding the long-term behaviour of classes of variable stars which vary on long time scales. For instance: the long secondary periods in pulsating red giants, mentioned above, were evident from AAVSO photometry a decade ago. Especially when these periods are superimposed on complex shorter-period pulsation modes, it takes many years of data to sort these periods out.

Another answer, of course, is that photoelectric photometry permits the study of small-amplitude variations. Previously, our knowledge of the behaviour of pulsating red giants was based largely on the study of Mira stars, with large amplitudes. Now, small-amplitude pulsators are being discovered by the thousands in our galaxt and others. But the study and understanding of bright variable stars, such as those in the AAVSO PEP program, are leading the way.

So the combination of long-term observation, and high-precision observation opens up important areas in the study of variable stars.