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COMMISSION 27: VARIABLE STARS[1]

(LES ETOILES VARIABLES)

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1. INTRODUCTION

For Commission 27 these triennial reports have traditionally been very compact literature reviews of all the fields relevant to our commission. For several triennia we have been discussing the relevance of them, and asking just who their readership is. It seems that only a few people read them, and fewer use them as introductions to the subject – supposedly one of their prime purposes. The major beneficiaries have been the writers, who have been forced to do three-year reviews of their subjects. The IAU EC gave us the option this triennium of a shorter, four-page report to which the majority of the SOC agreed.

Arguments in favor of this new, shorter report are: 1) Literature reviews are now much easier. Newcomers to the field may quickly find papers on any subject with a web search: go to http://adsabs.harvard.edu/abstract_service.html and enter the key words of interest. 2) Astronomical meetings have become much more common. The proceedings of these meetings are excellent places to begin literature searches, as there are always reviews of a wide range of sub-fields. For C27 since the last of these reports we have had IAU S181 (Provost & Schmider 1996), IAU S185 (Deubner et al. 1998), two biennial pulsation meetings, one in Los Alamos (Bradley & Guzik 1998) and IAU C176 in Budapest (Szabados & Kurtz 2000), IAU C175 on Be stars (Smith et al. 2000), the Tenth Cambridge Workshop on Cool stars for flare stars and stellar activity (Donahue & Bookbinder 1998), and many other relevant meetings. Particularly with proceedings of these meetings now mostly being published in the ASP Conference series, everyone who has access to this review has access to the proceedings. 3) With the new Division structure of the IAU, the reports on IBVS, GCVS and the archives of unpublished observations are now in the Division V report.

Thus, with superior up-to-date, comprehensive literature searches available on the web, most of the rest of this report is devoted to a few selected highlights of the last triennium.

2. LARGE-SCALE SURVEYS

In the last C27 report, Mike Jerzykiewicz pointed out that a section on "Variable Stars from Major CCD Surveys" had been intended, but the report for that section was lost in the mail. IAU Colloquium 176 (Szabados & Kurtz 2000) was on just that topic, so the proceedings cover the subject well. Here I give a brief overview.

Large-Scale CCD Surveys have, in only half a decade, transformed variable star research for both intrinsic variables, including pulsating stars, and for geometric variables. They are revolutionary. Already tens of thousands of variable star light curves have been obtained, and in just a few years the number of monitored stars will exceed one billion, and the

[1] C27 has a homepage at http://www.konkoly.hu/IAUC27/ with a facility for up-dating email addresses. Members are urged to do this.

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number of known variable stars will exceed one million! And this is only from ground-based surveys. Future space missions, COROT, MOST, MONS and GAIA will reach precisions of 1 or 2 ppm, thus detecting solar-type oscillations in other stars – the next really big step in helio- and asteroseismology. GAIA, to be launched in 2009, will obtain astrometry to 4 μas precision for $V < 12$, radial velocities to 3 km s^{-1} for $V < 17$, and time series photometry for 1 billion stars with $V < 20$!

We do not know how we are going to name all these variable stars. The Hipparcos parallax survey had 3157 new variables named in the traditional manner by the GCVS. Whether this is possible, or even desirable, with the flood of new data is contentious. The SOC of C27 has been discussing this problem with Nikolai Samus of the GCVS since the XXII GA in the Hague in 1994. No obviously superior naming system has been proposed to supplant the current one; ideas are welcome. The handling, storage, retrieval, and analysis of the vast amount of data being acquired by the surveys has yet to be standardized. That, plus the naming problem will need significant input from C27. See Samus et al. (2000) for further details.

In the naming of the many survey projects acronymania runs rampant. There are: AGAPE, ASAS, DIRECT, EROS, LOTIS, MACHO, MOA, OGLE, PLANET, ROTSE, STARE, TAOS, YSTAR, and more. See http://www.astro.princeton.edu/faculty/bp.html for links to all the home pages. As their primary goals, these projects study, or will study: microlensing from dark matter, brown dwarfs or planets; optical counterparts of γ-ray bursts; contact binary stars; detached eclipsing binary stars for distance measurements; and Kuiper Belt Objects. Some of them are even designed specifically to observe variable stars. A strong argument can be made that the successful detection of microlensing events, the original goal of many of these projects, has been eclipsed by the rich astrophysical results of the variable star data. Look at some of the MACHO results: 200,000 variable light curves identified from 30 million light curves analyzed. The numbers are astronomical. A MACHO Period-Luminosity diagram with 44790 variable stars plotted shows, among many other things, the fundamental and first-overtone Cepheid tracks separately without resort to drawing lines, or making calculations. What would Henrietta Leavitt have thought?

The "long" and "short" distance scales continue to be debated. During this triennium the distance modulus to the LMC was determined to be $\mu_{LMC} = 18.70 \pm 0.10$ from Cepheids using Hipparcos parallaxes to derive a zero point for the PL relation (Feast & Catchpole 1997), and was determined to be $\mu_{LMC} = 18.23 \pm 0.08$ from Red Clump recalibration and RR Lyrae stars in the OGLE database (Popowski 2000). Many other papers support each of these incompatible results. The Hubble constant, hence the age of the universe and its agreement, or disagreement with globular cluster ages, at least partially depends on which of these scales is correct.

Progress has been made on the long-standing puzzle of the Blazhko effect. New data from MACHO and OGLE far surpass anything that has been obtained in the last 90 years. The important new results from many analyses of these data are that RRc stars also show the Blazhko effect, but with much lower percentage than RRab stars, and many RRc stars seem to be doubly periodic with closely spaced frequencies, implying the presence of non-radial modes. These results support the resonant mode hypothesis. See Szabados & Kurtz (2000) for many papers on this subject.

3. MULTI-SITE CAMPAIGNS AND NETWORKS

It has long been recognized that the problem of aliases in data with time gaps is insurmountable for short-period variable stars: the Sun, pulsating white dwarfs, EC 14026 stars (see section 4 below), roAp star and δ Scuti stars, in particular. For the Sun, of course, there are many devoted multi-site networks of telescopes for helioseismic observations, such as GONG, BiSON, IRIS, and TON. But no such dedicated network exists for asteroseismic observations. Instead, there are groups of astronomers who apply for simultaneous observing time at sites well-spread in longitude to obtain continuous light curves. Some of these

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groups are: WET (Whole Earth Telescope), DSN (Delta Scuti Network), STEPHI (Stellar Photometry International), and STACC (Small Telescope Array with CCD Cameras).

The δ Sct stars are potentially the richest asteroseismic prizes on the upper main sequence with their many pulsation modes. While mode identification remains problematic (see Guzik 1999, Breger et al. 1999), in the last three years the network campaigns have made great progress increasing the numbers of confidently identified frequencies - a prerequisite for seismology. STEPHI has observed δ Sct stars for 10 years now with observations for 12 stars having been obtained. Noise levels are a few parts in 10^4 in amplitude, and up to 11 frequencies have been identified. See http://dasgal.obspm.fr/~stephi for further information. STACC has concentrated on δ Sct stars in clusters. This is to get more than one δ Sct star and comparison stars on a single frame, and because of the advantages of the additional astrophysical information available for cluster stars. The STACC 98 campaign was on BN Cnc and BV Cnc in Praesepe with at least 5 frequencies determined down to a noise level of about 5 parts in 10^4. See Frandsen & Pigulski (2000) and http://www.obs.aau.dk/~srf/projects/STACC.html for more details. By far the most successful campaigns, in terms of the numbers of frequencies identified, are those of the DSN and combined DSN/WET. The record is currently held by 4 CVn with 34 identified frequencies (see Breger 2000), many of which have variable amplitudes. For FG Vir the number is 24 frequencies; see Breger et al. (1999) for a discussion of mode identification attempts and pulsation modeling. See, also, http://dsn.ast.univie.ac.at/ where links to the Delta Scuti Newsletter can be found.

WET is the most sophisticated of the stellar seismology networks. It has been running since 1986 with, usually, two multi-site campaigns per year. Observations are coordinated during two-week observing campaigns from a central headquarters where real-time reductions are performed and instructions sent out to participating sites to maximize the effective use of the network and minimize data gaps. Workshops involving typically 50 participants from about 25 participating observatories are held biennially. WET primarily, but not exclusively, studies pulsating white dwarf and pre-white dwarf stars. It has been extremely successful with hundreds of frequencies determined, white dwarf masses constrained to precisions of a few hundredths of a $M_\odot$, masses of atmospheric H and He layers determined, and much more. See http://wet.iitap.iastate.edu/index.html for more information.

4. TWO NEW CLASSES OF VARIABLE STARS: EC 14026 STARS AND γ DOR STARS

The EC 14026 stars are extreme-HB stars which have been mostly stripped of their H envelopes. Pulsation with periods in the range 90-550 s was discovered in these stars just as this triennium began by a group of astronomers at the South African Astronomical Observatory (see Koen et al. 1999 for an introduction to the EC 14026 stars, and a guide to the large and growing literature on them), while independently such pulsation was theoretically predicted by a group in Montreal (see Charpinet et al. 1997). Fe opacity in a diffusively enhanced layer is the proposed pulsation mechanism. They pulsate in several radial or nonradial p modes, making them excellent candidates for asteroseismic study – especially since evolutionary models cannot yet explain why they are as they are, or how they get back up the AGB. Asteroseismic structural constraints will be very useful.

Particularly intriguing is the beautiful, and striking light curve of PG 1336 – 018 (Kilkenny et al. 1998). This star is an eclipsing binary with an orbital period of 2.4 h and two rapid pulsation modes with periods of 184 s and 141 s, and amplitudes of 10 mmag and 5 mmag, respectively. The potential is present for mode typing by tomography during the primary eclipse when the sdBV is progressively hidden by the ≈M5 secondary. A large amount of research continues on this star, and on the EC 14026 group. Keep watching.

The γ Dor stars have now been accepted as a fully-fledged new class of variable stars. Quoting from Kaye et al. (1999): "These stars typically have between 1 and 5 periods ranging from 0.4 to 3 days with photometric amplitudes up to $0\overset{m}{.}1$ in Johnson V. The

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mechanism for these observed variations is high-order, low-degree, non-radial, gravity-mode pulsation. γ Doradus stars constitute a new class of variable stars because they all have about the same mass, temperature, luminosity, and the same mechanism of variability. They are clearly not a sub-class of any of the other A/F-type variable or peculiar stars in this part of the HR diagram, and may offer additional insight into stellar physics when they are better understood (e.g., they may represent the cool portion of an 'iron opacity instability strip' currently formed by the β Cephei stars, the SPB stars, and the subdwarf B stars; they may also offer insight into the presence of g-modes in solar-like stars)." In addition, Handler (2000) has identified 70 new γ Dor candidates from Hipparcos photometry allowing him to identify an instability region in the HR diagram, and to discuss statistics of the group.

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