Transactions IAU, Volume XXVIIIA
Reports on Astronomy 2009–2012
Ian Corbett, ed.

doi:10.1017/S1743921312002840

COMMISSION 27 — VARIABLE STARS

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TRIENNIAL REPORT 2009-2012

1. Introduction

As research on variable stars continues at an ever growing pace, this report can only give a selection of research highlights from the past three years, with a rigorously abbreviated bibliography. The past triennium has been dominated by results of the CoRoT (Astronomy & Astrophysics 2009) and *Kepler* (Gilliland *et al.* 2010) space missions, stemming from their unprecedented photometric accuracies and large time bases.

Numerous conferences related to the field have taken place; the following list certainly is incomplete. Two of the biennial meetings on stellar pulsation were held in Santa Fe, USA (2009) and Granada, Spain (2011). Kepler Asteroseismic Science Consortium Workshops took place in Aarhus, Denmark (2010) and Boulder, USA (2011); CoRoT symposia in Paris, France (2009) and Marseille, France (2011). The Kukarkin Centenary Conference was held in Zvenigorod, Russia (2009) and IAU Symposium 272 on active OB stars in Paris (France, 2010). IAU Symposium 273 dealed with the Physics of Sun and Star Spots (Ventura, USA, 2010), IAU Symposium 286 with Comparative Magnetic Minima (Mendoza, Argentina, 2011). IAU Symposium 285 (New Horizons in Time Domain Astronomy, Oxford, UK, 2011) had substantial interest for C27. The American Association of Variable Star Observers held its 100$^{\text{th}}$ annual meeting 2011 in Boston, USA.

2. Science highlights

2.1. *Stellar activity*

A comprehensive review of the origin and properties of starspots was published by Strassmeier (2009), with special emphasis on the the possibility of detecting exoplanets around spotted host stars. The existence of spots for discovering planets and in studying possible star-planet interactions has recently been recognised.

Several papers have been devoted to the active star CoRoT-7 and its planet(s). The review by Pont *et al.* (2011) highlights the importance of a realistic treatment of both the activity and the uncertainties which are applicable to most small-planet candidates observed by CoRoT and *Kepler*. The combined presence of activity and additional errors precludes a meaningful search for additional low-mass companions.

Deming *et al.* (2011) developed a method to correct planetary radii for the presence of both crossed and uncrossed star spots. The exo-Neptune HAT-P-11b transits nearly perpendicular to the stellar equator, and the authors related the dominant phases of star-spot crossings to active latitudes on the star. Precise transit measurements over long durations may allow one to construct a butterfly diagram to probe the cyclic evolution of magnetic activity on the active K-dwarf planet-host star.

Osten *et al.* (2010) observed a large stellar flare and fluorescence from the dMe star EV Lac. The size of the flare, in terms of its peak X-ray luminosity, exceeded the non-flaring stellar bolometric luminosity, providing important constraints on the time-scales for energy storage and release in a stellar context.

Kolláth & Oláh (2009) and Oláh *et al.* (2009) demonstrated that time-frequency distributions provide useful tools for analysing the observations of active stars whose magnetic activity varies with time. Their technique applied to sunspot data revealed a complicated, multi-scale evolution in solar activity. Time variations in the cycles of 20 active stars based on decade-long photometric or spectroscopic observations show that stellar activity cycles are generally multiple and variable (see also Sect. 2.2).

Korhonen *et al.* (2009) presented simultaneous low-resolution longitudinal magnetic field measurements and high-resolution spectroscopic observations of the cool single giant FK Com. The maxima and minima in the mean longitudinal magnetic field are both detected close to the phases where cool spots appear on the stellar surface.

2.2. *Solar-like oscillations*

Oscillations in the Sun are excited stochastically by convection, as also they are in other stars with convective envelopes. CoRoT has contributed substantially to the list of main-sequence and subgiant stars with solar-like oscillations (e.g. Mathur *et al.* 2010 and references therein). A problem particularly present in F-stars (e.g. Benomar et al. 2009) was illuminated by CoRoT data: the short-mode lifetimes cause blending of some oscillation modes, thereby hampering mode identification.

A major achievement by CoRoT came from observations of hundreds of G- and K-type red giants showing clear oscillation spectra that are remarkably solar-like, with both radial and non-radial modes (e.g. De Ridder *et al.* 2009, Mosser *et al.* 2011). CoRoT continues to produce excellent results on red giants, main-sequence and subgiant stars.

The *Kepler* mission carried out a survey targeting more than 2000 main-sequence and subgiant stars for one month each. Solar-like oscillations were detected, and clear measurements of the large frequency separation for about 500 stars were made (Chaplin et al. 2011) – an increase by a factor of $\sim$20 over previous results. Some of these stars have been studied individually. The first results on two main-sequence stars and one subgiant provided evidence for mixed-mode oscillations in the latter (Chaplin *et al.* 2010).

Kepler detected solar-like oscillations in thousands of red giants (e.g. Hekker *et al.* 2011 and references therein), including some in open clusters (e.g. Basu *et al.* 2011), enabling asteroseismic studies that would not have been thought possible only a few years ago. For example, the gravity-mode period spacings in red giants provide a means to disentangle the evolutionary phases of hydrogen- and helium-burning in red-giant stars (Bedding et al. 2011), an otherwise difficult task given the similarities in the mass, luminosity and radius of these two groups. Miglio *et al.* (2010) described the first detection of the seismic signature of the helium second-ionization region in red-giant stars, opening up the interesting possibility of determining seismically the helium content of their envelopes.

García *et al.* (2010) presented the first strong evidence for cyclic frequency variations associated with the presence of a stellar magnetic-activity cycle in a star other than the Sun. Seismic signatures of stellar activity cycles, in combination with additional information such as differential rotation, extent of convective envelope, etc., have the potential to increase substantially our understanding of mechanisms for magnetic-field generation and evolution. In the solar case, Fletcher *et al.* (2010) hypothesized a second dynamo based on quasi-biennial solar oscillation frequency variations.

Solar-like and heat-engine oscillations are not mutually exclusive. Both may in fact operate in a star provided that the surface convection layer is thin (Samadi *et al.* 2002). There is evidence from *Kepler* data for solar-like oscillations in at least one δ Scuti star (Antoci *et al.* 2011). There has even been a suggestion that sub-surface convection in B-type stars could excite solar-like oscillations (Cantiello *et al.* 2009, Belkacem et al. 2010). Meanwhile, Degroote *et al.* (2010) suggested that stochastically-excited oscillations are revealed in CoRoT photometry of the O-type star HD 46149.

2.3. *Classical and heat-driven main sequence pulsators*

The enigmatic Blazhko effect (amplitude/phase modulation) turns out to be very common in RR Lyrae stars, as ground-based (Jurcsik *et al.* 2009), CoRoT (Szabó *et al.* 2010a), and *Kepler* results confirm (e.g. Kolenberg *et al.* 2010). The pulsations in at least some RR Lyrae stars are remarkably stable (Nemec *et al.* 2011).

Space photometry data of RR Lyrae stars reveal previously unseen features in Blazhko stars, such as period doubling (Kolenberg et al. 2010) and additional modulations, which are not fully understood yet (Benkő *et al.* 2010, Guggenberger *et al.* 2011). This is also the case for RR Lyr itself, successfully observed by *Kepler* (Kolenberg *et al.* 2011). Period doubling has been traced to a 9:2 resonance between the fundamental mode and the ninth radial overtone (Szabó *et al.* 2010b), confirmed by models of Buchler & Kolláth (2011). Their results may even explain the irregular amplitude modulation which recent observations reveal. At last we may come closer to an explanation for the Blazhko effect.

RR Lyrae stars continue to fulfill their role as indicators, not only of distance but also of tracers of galaxy formation histories. They are increasingly being used by large-scale surveys such as SDSS (e.g. Sesar *et al.* 2010). In particular, studies of the so-called Oosterhoff dichotomy, which until recently were confined to the Milky Way and its nearest neighbours (e.g. Catelan 2009), can now probe greater distances (e.g., Fiorentino *et al.* 2010), and even include globular clusters as far away as M31 (Clementini *et al.* 2009).

Engle *et al.* (2009) reported X-ray emission of three bright Cepheids observed with XMM-Newton and Chandra. Despite differences in spectral type and pulsation properties, the Cepheids have similar X-ray luminosities and soft-energy distributions. Such high energy could arise from warm winds, shocks or pulsationally-induced magnetic activity.

Herschel images of Mira (Mayer *et al.* 2011) reveal broken arcs and faint filaments in the ejected material of the primary star. Mira's IR environment appears to be shaped by the complex interaction of its wind with its companion, the bipolar jet and the ISM. High-angular resolution Chandra imaging by Karovska *et al.* (2011) indicated focused-wind mass accretion, a "bridge" between Mira A and Mira B, indicating gravitational focusing of the Mira A wind whereby components exchange matter directly as well as by wind accretion. That greatly helps explain accretion processes in symbiotic systems and other detached and semi-detached interacting systems.

The "Cepheid Mass Problem" (the mismatch between masses computed from evolutionary tracks and hydrodynamic pulsation calculations for classical Cepheids) is a fundamental test of stellar-evolution models. The problem may be related to convective overshoot and possible mass loss (e.g. Neilson *et al.* 2011). Marengo *et al.* (2010) discovered an infrared nebula and a bow shock around δ Cephei and its hot companion, supporting the hypothesis that δ Cephei may be currently losing mass.

The *Kepler* characterization of the variability in A- and F-type stars (Grigahcène *et al.* 2010, Uytterhoeven *et al.* 2011) revealed a large number of hybrid δ Sct/γ Dor pulsators, thereby opening up an exciting new channel for asteroseismic studies.

Intriguingly, Kurtz *et al.* (2011) presented the first example of a star that oscillates around multiple pulsation axes. Evidence for the presence of torsional modes was also given (also a first). Sousa and Cunha (2011) gave the first theoretically-based explanation for the diversity found observationally in the atmospheric behaviour of the oscillations of roAp stars; that may have important consequences for the study, based on seismic data, of atmospheres of roAp stars.

2.4. *Pulsation in hot subdwarf and white dwarf stars*

Pulsating hot subdwarf stars include the V1093 Her variables, subdwarf B (sdB) stars exhibiting gravity mode-pulsations, V361 Hya variables, sdB stars exhibiting pressure-mode pulsations, DW Lyn variables, hybrids showing both V1093 Her and V361 Hya type variability, and a unique subdwarf O pulsator. Pulsating white dwarf stars include the GW Vir variables, the hottest white or pre-white dwarfs. Among cooler stars they also include the helium-rich V777 Her (DBV) stars, the carbon-rich hot DQV pulsators and the classical hydrogen-rich ZZ Ceti (DAV) stars.

Among hot subdwarfs the first *Kepler* survey found only one V361 Hya variable in the field, but several V1093 Her variables were identified (Østensen *et al.* 2010). Those discoveries spawned an industry of more detailed analyses and follow-up surveys (e.g. Reed et al. 2010, Pablo *et al.* 2011, and references therein).

Detailed asteroseismic modelling for a number of sdB stars has mostly been based on the more mature CoRoT data, although *Kepler* data are also now having an impact (e.g. Charpinet *et al.* 2011, and references therein). *Kepler* has had less influence in the pulsating white dwarf arena; however, representatives of the ZZ Cet and V777 Her classes in the *Kepler* field (Hermes *et al.* 2011, Østensen *et al.* 2011) have now been found.

Larger-scale surveys continue to find more variables in *all* of the classes described above. The recent literature contains too many examples of surveys to be listed individually; it is the sum of contributions, rather than any individual publication, which makes this a progressive field of research. The possibility that any of these discoveries might represent something really new is investigated in follow-up observations of individual stars. Two pulsating sdB stars have attracted particular attention: CS 1246 is a radial pulsator in a close binary; fortnightly variations in the ephemeris are caused by light-travel time delays as the star orbits a $0.12\,M_\odot/\sin i$ companion (Barlow *et al.* 2011). Long-period variability has been confirmed in the sdB star LS IV$-14°116$ (Green *et al.* 2011), an object that is chemically extremely peculiar (Naslim *et al.* 2011). It has been suggested that the pulsations may be excited by the ϵ mechanism in He-burning shells (Miller Bertolami *et al.* 2011), possibly making it the first pulsator known to be excited in this way.

The asteroseismic properties of white dwarfs of all four types (DAV, DBV, DQV and DOV) have been explored, with the DBV prototype GD 358 coming under close scrutiny (e.g. Montgomery *et al.* 2010), partly in the wider quest to characterise convection physics in DAV and DBV white-dwarf atmospheres using non-linearities in the light curves. Evidence that the DOV prototype GW Vir rotates as a solid body (Charpinet *et al.* 2009) addresses the long-standing angular-momentum question for white dwarfs: angular momentum must be removed at an earlier phase of evolution.

3. Catalogues and data archives

The flow of new variable-star discoveries makes compilation of new Name-Lists in the GCVS system a very complicated task. Thus, the 80th Name-List will contain more than

6000 new variables and is being published in three parts (part 1: published, part 2: end 2011, part 3: 2012). Samus *et al.* (2009) have published a catalogue of accurate equatorial coordinates for variable stars in globular clusters.

The Div. V WG for Spectroscopic Data Archives was wound up in 2010 March. In operation since 1992, it had accomplished – or witnessed – some valuable changes in attitudes towards archiving observations of spectra. Having fulfilled its prime objective in those achievements, a new bottleneck in the form of creating archives of *reduced* spectra was recognised, in particular for echelles. Efforts to reorient the WG towards "Pipeline Reductions" did not have the right audience or the right platform for adequate revitalization. The mission to design a dependable future for astronomy's heritage of spectra on photographic plates has been actively taken over by the Task Force for the Preservation and Digitization of Photographic Plates (PDPP, Comm. 5).

4. Projected future of the Commission and its science

Currently, Commission 27 is dominated by people working on stellar pulsation. Given the coming changes in the structure of the IAU, we need to consider whether to keep the current comprehensive Commission, albeit with a better balance between its different fields, or to propose a subdivision following the nomenclature of variable stars.

Concerning science, we are awaiting the launch (foreseen in 2013) of the Gaia mission. It will provide astrometry, photometry, spectrophotometry and spectroscopy of $\sim 10^9$ objects with $6 < V < 20$ including variable stars, over a projected mission length of 5 years, with an average number of measurements of ~ 70 per object. BRITE-Constellation comprises six nanosatellites to be launched sequentially in 2012 - 2013, aiming at variable stars with $V < 4$. It will be the first using at least two photometric filters. Regrettably, the PLATO mission has not been selected for implementation in the near future.

The VISTA ESO Public Survey (Minniti *et al.* 2010) will provide information on about 10^6 variable stars in several infrared passbands, and going several magnitudes deeper than 2MASS. The survey totals $\sim$1929 hours of observations, spread over $\sim$5 years, and includes $\sim$35 known globular clusters and hundreds of open clusters towards the Galactic bulge and an adjacent part of the disk. The (predominantly) spectroscopic SONG global telescope network is still progressing, and aims to make precise radial-velocity measurements with a strong focus on investigating solar-like oscillations.

Acknowledgments

The OC thanks Elizabeth Griffin and Nikolai N. Samus for their contributions.

Gerald Handler
President of the Commission

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https://doi.org/10.1017/S1743921312002840 Published online by Cambridge University Press

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https://doi.org/10.1017/S1743921312002840 Published online by Cambridge University Press