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INTER-DIVISION IV-V / WORKING GROUP Ap AND RELATED STARS

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TRIENNIAL REPORT 2006 - 2009

1. Introduction

The diversity of physical phenomena embraced by the study of Chemically Peculiar (CP) stars results in an associated research community with interests that are equally diverse. This fact became once more evident during the *CP#Ap Workshop* that took place in Vienna (Austria) in September 2007, and which gathered over 80 members of this research community. Besides the excellent scientific outcome of the meeting, during the workshop the community had the opportunity to discuss its organization and plans for the future. Following on those plans, the Working Group has submitted a proposal for a Joint Discussion during the IAU XXVII General Assembly, in Rio de Janeiro, which has meanwhile been accepted. Moreover, through an ApN newsletter forum, the Working Group has compiled requests from the community concerning atomic and related data. These requests have been put together and will be shared with Commission 14.

Besides the dedicated workshop mentioned above, a number of conferences and workshops with sessions directly related to the physics of subgroups of CP stars either took place, or will take place between September 2006 and July 2009. These include the conferences: *Magnetic Stars 2006* (SAO, Russia, September 2006); *The Future of Asteroseismology* (Vienna, Austria, September 2006); *Non-LTE Line Formation for Trace Elements in stellar atmospheres* (Nice, France, Aug 2007), *9th International Colloquium on Atomic Spectra and Oscillator Strengths for Astrophysical and Laboratory Plasmas* (Lund, Sweden, Augustus 2007); *Interpretation of Asteroseismic Data* (Wroclaw, Poland, June 2008); the symposium *Asteroseismology and Stellar Evolution* and the symposium *Star Clusters - Witnesses of Cosmic History* (both of JENAM 2008, Vienna, Austria), and IAU Symposium No. 259 *Cosmic Magnetic Fields: from Planets, to Stars and Galaxies* (Tenerife, Spain, November 2008). Members of the CP star community have been (or are) involved in all these meetings, either as organizers or as speakers.

This involvement of members of the CP star community in a vast number of scientific events highlights well the significant development of CP star research over the past few years, which was only possible due to the increasing number of excellent instruments available to the community. In particular, ground-based spectroscopic and spectropolarimetric instruments such as UVES and HARPS (ESO) and ESPaDOnS (CFHT) and

space-based instruments such as that carried by the Canadian-led satellite *MOST* and the French-led satellite *CoRoT* have started, or continued, to provide data of excellent quality, feeding, simultaneously, the development of sophisticated stellar modelling. Most scientific results have been published in international journals and are available to the community in archives such as ADS or astro-ph. For those readers interested in searching the literature for articles specifically on CP stars research, we suggest a visit to the site of the ApN newsletter (<ams.astro.univie.ac.at/apn>). On this site, the reader will be able to find all articles that have appeared in the ADS in the recent past, which are in some way related to CP stars research. An important summary of recent and ongoing research work on CP stars is published in the proceedings of the Vienna *CP#Ap* Workshop (CoSka, vol. 38). In the following section we will summarize some recent highlights that directly concern the study of CP stars.

2. Highlights of CP stars research

In a letter *Weather in stellar atmosphere revealed by the dynamics of mercury clouds in alpha Andromedae*, Kochukhov *et al.* (2007) presented the discovery of secular evolution of mercury abundance spots in the brightest HgMn star α And. Seven-year monitoring of the surface spots in this non-magnetic chemically peculiar star revealed previously unknown non-magnetic structure formation process akin to weather in planetary atmospheres. These results have profound implications for our understanding of the radiative diffusion, mixing, and resulting heavy element enrichment of the atmospheres of non-magnetic CP stars and have consequences in the broader context of the studies of dynamical structure formation and self-organization in nature. Investigation of α And was performed using ultra-high signal-to-noise line profile observations obtained at Dominion Observatory (Canada) and Special Astrophysical Observatory (Russia). These data were analysed with the help of Doppler imaging technique.

Another very exciting result was the first interferometric determination of the angular diameter of a roAp star, specifically the brightest roAp star, α Cir Bruntt *et al.* (2008). From the latter, a new, independent, determination of the effective temperature of the star became possible. The value found $T_{\rm eff} = 7420 \pm 170$ K is smaller that all values published in the literature, supporting the suspicion that systematic errors may affect the determinations of effective temperatures of CP stars.

Atmospheric research was also a topic of intense research. The Vienna team on Stellar Atmospheres and Pulsating Stars (SAPS) (<ams.astro.univie.ac.at/>) Kochukhov & Shulyak (2008), Khan & Shulyak (2007) has calculated and analysed a grid of model atmospheres with individual abundances pattern and has shown that among others, Si, Cr and Fe are the most important elements which produce most noticeable effects in the model atmosphere structures of CP stars. On the more theoretical side, diffusion in the presence of magnetic fields has been considered by Alecian & Stift (2007) under the assumption of equilibrium stratification in the atmosphere, and shown to be consistent with a number of abundance profiles and surface maps derived from Doppler imaging of Ap stars.

Concerning pulsations, the combination of space photometry from MOST (Canada) and ground-based high-resolution spectroscopy from UVES (ESO) has provided a unique opportunity to study the pulsational characteristics of several roAp stars Gruberbauer *et al.* (2008), Ryabchikova *et al.* (2007), Huber *et al.* (2008), Sachkov *et al.* (2008). The pulsation analysis in the stellar atmospheres was supplemented by the NLTE line formation study of the rare-earth elements Nd and Pr, which spectral lines usually show the

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highest pulsation radial velocity amplitudes. All together, these studies provide unique new material for the further development of theoretical models that may explain the details of pulsations in this most interesting class of pulsators.

On the theoretical side, the long debated issue of mode reflection in the atmospheres of roAp stars was addressed by Sousa & Cunha (2008). The authors have shown that the magnetic field provides a natural mechanism for the reflection of a fraction of the mode energy. Although part of the mode energy is indeed lost every pulsation cycle through running acoustic waves in the atmosphere and through running magnetic waves in the interior, the energy kept in the mode might be sufficient for the perturbations to be over stable, so far as enough energy is input in each cycle through the opacity mechanism.

Another important step that is being undertaken in this field of research is the observation of statistically meaningful samples of stars, to characterize their observational properties and to learn about aspects of the underlying physics. Kudryavtsev *et al.* (2006) published the results of spectropolarimetric observation of 96 chemically peculiar stars acquired at a 6 m telescope (SAO RAS, Russia), among which magnetic fields have been detected in 72 stars. The authors demonstrate that selecting candidate magnetic stars by considering their photometric indices, in particular strong anomalies of the continuum flux depression at 5200 Å, considerably increases the detection rate. Adelman & Woodrow (2007) summarized the published variability studies of mCP star performed by Adelman and his collaborators at the 0.75 m Four College APT (FCAPT) at the Fairborn Observatory. Sixty-eight of 70 mCP stars studied were found to be variable. This means that all mCP stars can be considered to be variable and by inference that all class members are variable. Moreover, Adelman(2008) noted that about 12% of the mCP stars with published data from the FCAPT have variable seasonal light curves in the Strömgren system, indicating that their rotational axis must be precessing about the magnetic axis. Finally, an important step towards the understanding of the origin and evolution of stellar magnetic fields in being undertaken, based on a survey of magnetic fields in Ap/Bp stars and their progenitors e.g.]landstreet08,alecian08 with the spectropolarimeter ESPaDOnS (CFHT).

3. A look into the future

Most of the exciting results from high spectral- and time-resolution spectroscopy and spectropolarimetry of various subgroups of CP stars are very recent. Several new instruments, have just became or are expected to become available in the near future, opening new windows in studies of CP stars.

The NARVAL spectropolarimeter at TBL (Pic du Midi Observatory (<www.ast.obs-mip.fr/projets/narval/v1/>) was commissioned in November 2006. It is the world's first astronomical facility worldwide fully dedicated to stellar spectropolarimetry, and in particular to the study of stellar magnetic fields. It will provide large amounts of observing time to the community and will allow for long-term monitoring and for surveys of various types of CP stars.

The project *Magnetism in Massive Stars* (MiMes, PI G. Wade (<www.physics.queensu.ca/∼wade/mimes>) was selected as a CFHT Large Program and was allocated large amount of observing time with the ESPaDOnS spectropolarimeter for the period 2008-2012. This observing project, which includes 42 co-investigators, aims at improving our knowledge of the basic statistical properties and the structure of massive star magnetic fields, promising a new insight into the understanding of stellar magnetic field origin and evolution.

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The 0.5 m ASTRA Spectrophotometric Telescope is nearing completion at the Fairborn Observatory (USA) <astra.citadel.edu>] (Adelman *et al.* 2007) with scientific observations expected to begin before the 2009 IAU GA. These data, with a resolution of 14 Å in first order and Å in second order, along with Balmer line profiles for each star should greatly help in the determination of effective temperature and surface gravity of CP stars. Improvements in the understanding of the photometric variability of mCP stars and binarity of Am and HgMn stars are also expected.

The Uppsala Astronomical Observatory in cooperation with Utrecht University, Rice University, and Space Telescope Science Institute is developing a polarimetric module for the ultra-stable spectrometer HARPS at the 3.6 m ESO telescope in La Silla. The polarimeter design was approved by ESO and assembly of the instrument will soon commence. Commissioning at the telescope is expected in 2009. The polarimetric upgrade of HARPS will enable high-resolution Stokes parameter observations from southern hemisphere and thus will be of great interest for the studies of magnetic fields in CP stars.

Looking ahead, beyond 2009, we may expect that ambitious projects such as *Gaia* (ESA: <www.rssd.esa.int/Gaia>) and WSO-UV (Russia: <wso.inasan.ru/>) will have a major impact in the understanding of CP stars' observational properties. That, in turn, will provide us with further opportunities to progress in the understanding of different physical processes, such as rotation, magnetic fields, diffusion and pulsation, that contribute to the diversity of observational properties that are found among these fascinating objects.

The diversity of theoretical and observational challenges faced in the study of CP stars has potential to attract a vast community, including researchers whose central interests are spread over different astrophysical contexts. The Working Group on *Ap and Related Stars* provides a privileged way to link together this vast community, promoting the constant interaction among its members.

Margarida S. Cunha
chair of the Working Group

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