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10th Meeting of the European Working Group on Chemically Peculiar Stars

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On October 5 and 6, 1983 the European Working Group on Chemically Peculiar Stars (CP Stars, formerly called Ap Stars) convened its 10th meeting at the ESO headquarters in Garching. After the opening, Dr. Herman Hensberge from the Vrije Universiteit Brussel gave a seminar to the ESO audience on "Progress of Ap research at ESO". In what follows we shall provide the reader with the essence of his talk.

The foundation of the European Working Group on CP Stars dates back to autumn 1978 (more precisely and more astronomically: to J. D. 2443793.917) when on the occasion of a workshop on Ap stars in the Infrared, held at the Vienna Observatory, half a dozen Belgian and Austrian astronomers got together and decided that the unsatisfactory situation concerning data collecting in Ap research should be removed by coordinated planning of the observations, especially at ESO, and by more intense exchange of information concerning available, but unpublished data.

The first requirement has been met since by organizing semiannual meetings before the deadlines of ESO applications. These meetings are usually hosted by one of the collaborators of the Working Group (WG), i.e. his institute, but also by ESO. This way Vienna, Paris, Brussels, Liège, Catania, ESO-Garching, Trieste, Göttingen, Mons and now again ESO have been our meeting places since spring 1979.

The second point has been tackled by issuing so far 10 times *A Peculiar Newsletter* (eds. H. Hensberge, Gh. Deridder, W. van Rensbergen, Brussels) containing information on existing data, planned observations and submitted papers. Due to its important role it has become a worldwide means of communication and serves also the IAU Working Group on Ap Stars.

At the moment astronomers from six European countries participate actively in the WG: Austria (Maitzen, Rakosch, Weiss), Belgium (Deridder, Hensberge, Manfroid, Mathys, Renson, van Santvoort), France (Floquet, Gerbaldi, Megessier, Morguleff), Germany (Hössler, Kroll, Schneider, Vogt, Voigt), Italy (Catalano, Faraggiana), Yugoslavia (Pavlovski). There is some cooperation also with Switzerland and with eastern and non-European countries.

Our scientific goal is to collect data on the peculiar properties of the CP stars which encompass slower rotation compared to the normal stars, strong metal line spectra, strong organized magnetic fields, often with reversing polarity, strong spectrum variability and recently pulsational instability.

The model of the "Oblique Rotator" which foresees a non-zero angle between the magnetic and rotation axes in these stars explains successfully the observed phase relationship between these phenomena.

Unexplained, however, is the question of the origin and the evolutionary time scales of these phenomena, i.e. magnetic fields, abundance anomalies, slow rotation. A number of theories and hypotheses have been put forward to explain the formation of peculiarities. Havnes and Conti (1971) have qualitatively shown that the interaction of the rotating magnetosphere of a magnetic Ap star with the interstellar medium produces both the deceleration of stellar rotation and the building up of abundance anomalies around the magnetic poles. Michaud (1970) takes diffusion of elements due to the selective effect of the radiation field on different elements as the mechanism for abundance anomalies. Strittmatter and Norris (1971) advocate mass loss along the polar field lines as cause for breaking of the rotation, while Fleck (1981) recently proposes hydromagnetic deceleration by the stellar magnetic field without mass loss.

The important question, where the strong magnetic fields come from, is answered either by the fossil field hypothesis or by a dynamo theory.

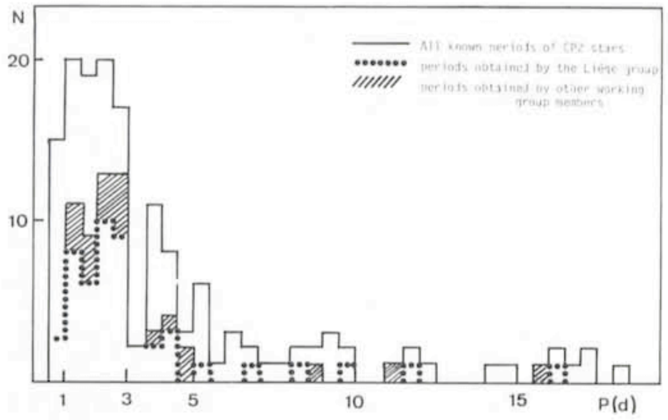

Fig. 1: *Histograms of published rotational periods (in days) of CP2 stars.*

What can observers contribute to clear up the darkness about the origin and the mechanisms giving rise to the appearance of peculiar and magnetic stars constituting roughly 10 % of the main-sequence stars of spectral types B5–F0?

Certainly, we can give theory strong constraints by finding out whether or which significant evolution of the observed peculiarities takes place on the main sequence. Thus, one direction of our efforts is the investigation of the rotational periods of the CP stars and their distribution with spectral type. Fig. 1 shows a histogram of rotational periods and visualizes the important contribution made by the colleagues of Liège and other members of our WG.

While historically some of the variation periods (= rotation periods according to the Oblique Rotator model) were obtained on the base of spectrum variability analyses, our work is nearly exclusively based on the search for photometric variability which very conveniently has been done at one of the small telescopes on La Silla (the 50 cm Danish, the 50 cm ESO and the 60 cm Bochum telescope).

As pointed out above, a general feature of the whole group of CP2 stars is slow rotation. This statement, however, does not apply to each object in this group. The reality is better described by saying that one finds CP2 stars with periods comparable to those of normal stars (= one day and less) of the same spectral domain, and also slower rotation of all degrees up to such long rotation periods that some stars take even many years to spin around their axes. Thus from this observational fact we may safely conclude that slow rotation is not necessary as starting condition for peculiarity, but is rather the result of the real cause of it.

It appears that too many CP2 stars are very slow rotators. As one result of our work we found that at least 4 % of them have periods longer than one month, but it could be even as large as 16 %. Therefore we started a campaign in our WG for monitoring apparently constant CP2 stars over time intervals of years. It will be very important to obtain the distribution of long-period stars over the whole spectral range of peculiar stars, since the time scale of braking can be checked considering the different main-sequence life times. A complete survey of the rotational behaviour of CP2 stars should clarify whether a single or more than one mechanisms/parameters are responsible for the rotational braking. A bimodal distribution in the histogram of rotational periods would point to the latter situation.

Some age information will also be available after the location of CP2 stars perpendicular to the galactic plane will have been established. After Vogt and Faundez (1979) had published their Strömgren photometry for 340 southern CP2 stars (obtained at the ESO 50 cm telescope) we started in our WG a programme for measuring β indices of these stars at the 50 cm Danish telescope. After a discussion of the applicability of Crawford's (1978) luminosity calibration to peculiar stars we should be able to map the galactic distribution of these stars.

A more direct input of the influence of time on peculiarity parameters will be received by observations of peculiar stars in open clusters. A number of studies of that kind have been carried out by different authors, mainly attempting to derive the frequency of peculiar stars in clusters as a function of age. The search for CP2 stars has always been based on spectroscopic identification. Since the average brightness of CP2 stars in open clusters is several magnitudes lower than that of the peculiar field stars, the spectroscopic search method implied enormous amounts of observing time at relatively large telescopes. As a result, the number of clusters surveyed is too low for significant statistical results to be derived, and a strong bias for the more luminous (= Silicon) peculiar stars was introduced.

Our WG has been carrying out a programme (starting Oct. 1979) searching for CP2 stars in open clusters using the photoelectric method proposed by Maitzen. This technique measures the depth of the broad band flux depression feature around 5200 Å by 3 intermediate-band filters centred on 5000, 5215 and 5480 Å, respectively (they are called "$g1$, $g2$ and y"). An index "a" is formed by subtracting the measurement in $g2$ from the mean of $g1$ and y. This index will deviate by 0.01 or more (up to hitherto 0.1 mag) from the index of a normal star of the same colour ($b–y$, $B–V$ or else) if the star exhibits a λ 5200 depression feature. Maitzen and Vogt (1983) have very recently shown by their observations of 339 southern CP2 stars (obtained at the ESO 50 cm telescope) that virtually all of the spectroscopically identified CP2 stars show a significant deviation $\Delta a = a(\text{CP2}) - a(\text{normal})$. Therefore, Δa is an ideal tool for detecting CP2 stars, since it is based on a broad-band feature, measurable with rather small size telescopes.

So far we have carried out the search for CP2 stars in 24 open clusters, for 9 clusters the results have been published (Maitzen and Hensberge, 1981; Maitzen and Floquet, 1981; Maitzen, 1982; Maitzen and Wood, 1983) and for 4 others preliminary results are available.

We hope to double the number of clusters surveyed in the next 3 years. The overwhelming majority of observations was obtained at the ESO 50 cm and 1 m telescopes. Some observations were made at CTIO (1 m), Catania (90 cm) and Hvar (Yugoslavia, 60 cm). In Fig. 2 we present a plot of the cluster results versus the logarithm of age for the first 13 clusters studied. From this we cannot yet deduce a clear-cut dependence of the frequency of CP2 stars on age, but obviously much more data should be obtained before reaching any reliable conclusion.

In addition to using Δa as identification criterion for CP2 stars one can consider this index as parameter quantitatively describing the peculiarity of the stars and try to find whether it exhibits any systematic variation with time (= age of the cluster). Of course, one tries to relate the phenomenological

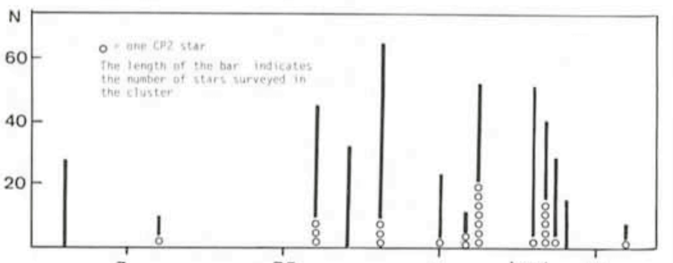

Fig. 2: *Result of CP2 star search in 13 open clusters as a function of the logarithm of age.*

peculiarity parameter to a physical mechanism. Broad autoionization features of Si II have been proposed to account for most of the λ 5200 depression. Other authors have suggested bound-free transitions, or just a local increase of the number of absorption lines around λ 5200. All of these explanations fail to describe consistently the behaviour of the λ 5200 feature. A more promising approach is to consider the empirical correlation of the strength of the λ 5200 feature found by Cramer and Maeder (1980) with the strength of the magnetic field. This relationship saturates at 5,000 Gauss. We can therefore ask, whether Δa is a measure of the (scalar) surface magnetic field. Increase of opacity can be explained by increase of Zeeman splitting of the individual lines with increasing field strength. This increase halts when the sigma and pi components of the magnetic splitting are fully separated; thus we observe the saturation of this effect. For lines on the flat part of the curve of growth the Zeeman splitting should produce a net linear polarization since the pi component can no longer be as strong as both sigma components together. In regions with enhanced line frequency, such as the λ 5200 feature, one can therefore hope to observe a measurable linear polarization if there is a significant transversal magnetic field component. A programme to measure this linear polarization in CP2 stars is under way in the framework of our WG. From a preliminary analysis of the variation of Δa during the rotational cycle for about 30 CP2 stars (based on observations at the 60 cm Bochum telescope, but also at the 50 cm ESO and the 90 cm Catania telescopes) we draw the conclusion that the behaviour of Δa is in accordance with the variation behaviour of the surface magnetic field.

Hence, we obtained the very valuable result that the broadband index Δa represents (with the restriction of the 5kG saturation) the magnetic field strength in CP2 stars. Thus, we can expect to assess any possible dependence of the magnetic fields on age measuring Δa for CP2 stars in clusters. This increases the value of Δa over a mere detection criterion for CP2 stars.

Another parameter – besides the magnetic field – justifies to call CP2 stars truly peculiar: the observed overabundances of Silicon, Strontium, Rare Earths and the Iron Group elements. Overabundances by a factor of up to 10^5 relative to the sun are reported. However, such extreme overabundances are more and more contested since modern atomic data, mainly the oscillation strengths of the exotic elements, do not seem to support such large factors. Furthermore, improved models of CP2 star atmospheres which take into account line blanketing of more than 900,000 lines also support this trend. But in any case, nobody doubts that some elements are clearly overabundant in CP2 stars. The most widely accepted theory for explaining the chemical surface anomalies is the diffusion theory put forward by Michaud (1970) and subsequently further developed by other authors. Diffusion acts individually on the chemical elements in the stellar atmospheres, depending on the balance between gravitational settling and radiation pressure lifting (the latter depending on the opacity provided by the individual elements under the actual atmospheric conditions). Therefore, diffusion will modify the surface abundances in both directions: some elements will become overabundant, while others will show up as underabundant. The latter applies to Oxygen, Helium, Carbon, Nitrogen and Neon, among others.

Presently, our WG members Faraggiana, Floquet, Gerbaldi and van Santvoort try to determine these underabundances with an unprecedented accuracy using the RETICON detector with the CAT Echelle Spectrometer. A major problem is the underabundance of Magnesium predicted by the diffusion theory. The results obtained so far, however, show that Mg has essentially solar abundance. Observations of the resonance lines at 2795 and 2803 Å for very few stars are in favour of a slight underabundance of Mg II. Observations of the near IR lines of Mg II will permit to extend the analysis to as wide a range as possible in wavelength in order to obtain information from atmospheric layers at different depths.

The cosmic abundance of Li, Be and B are very low compared to those of the neighbouring elements. Therefore one can expect that only their resonance lines will be observable. The lithium abundance, e.g., can be determined only by the resonance doublet of Li I at 6707 and 6708 Å. These observations were recently performed at La Silla and the data are currently evaluated.

Another fascinating aspect of CP2 stars is the instability against pulsation – at least of some of them. As reported recently by Kurtz (1982) and, in this journal by Weiss and Schneider: (1983a), radial as well as non-radial pulsation has been detected among these stars. Currently we are observing the known non-radially pulsating CP2 stars with the 90 cm Dutch telescope and the Walraven five-channel photometer in order to identify the pulsation modes. A reliable mode identification is crucial for a theoretical discussion of the pulsation frequency spectrum. Pulsation of CP2 stars is potentially a powerful tool for learning more about the structure of these stars and in particular the role of their relatively strong magnetic fields. The Walraven VBLUW photometer at ESO is an excellent instrument for determining the colour dependence of pulsation. With these photometric data on the pulsational behaviour we will be able to put constraints on possible modes based on a linear non-radial pulsation theory.

The surface brightness (*S*) is defined as the flux radiated from the visible stellar hemisphere towards the observer and is expressed in magnitudes. The flux (*F*) is given by the ratio of the total luminosity (*L*) to the surface area (*A*). Wesselink (1969) has shown that the surface brightness in the *V* band is nicely correlated with a colour index such as (*B–V*) and is therefore directly observable. In a first order approximation one can calculate the brightness variation according to:

$$\Delta m = \Delta S - 1.086 \times \Delta A/A$$

The variation of the projected area of the photosphere (= $\Delta A/A$) can be determined from radial velocity measurements after appropriate corrections for limb darkening and projection effects have been applied. The fundamental papers in this field are published by Dziembowski (1977), Balona and Stobie (1979a, b) and Balona (1981).

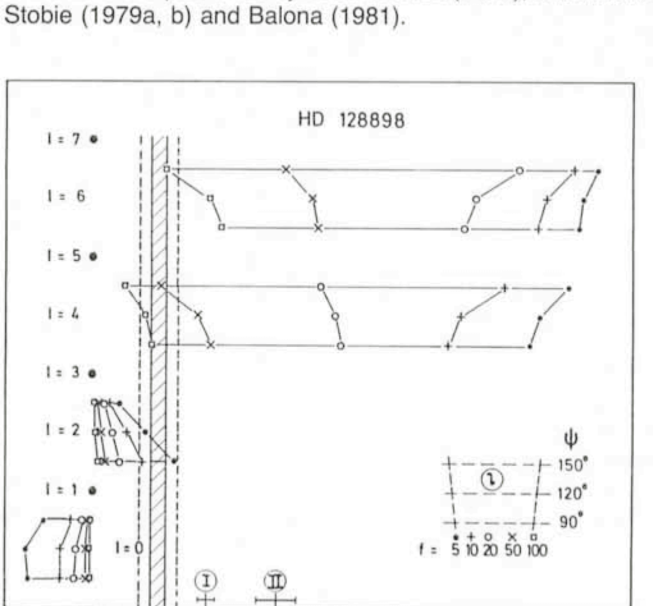

Fig. 3: *Pulsation mode determination diagram. For details see text.*

Basically, one uses diagrams like that given in Fig. 3 for mode identifications (Weiss and Schneider, 1983b). The abscissa is calibrated in phase differences between brightness and flux variations. The linear pulsation theory tells that this phase difference depends not only on the pulsation mode *l*, but also on the phase lag (ψ) between brightness and radial velocity variations and on the value of *f*, a parameter which characterizes the relative importance of the flux variations in the total luminosity variation. A ψ of about 120° can be expected for CP2 stars. The shadowed area in Fig. 3 represents our observed phase difference for HD 128898 (α Cir), Ⓘ represents the corresponding value for HD 101065 and Ⓘⓘ for HD 83368 as determined by Kurtz (1982). From our figure it is evident that more observations and in particular an improved theory are required, if one considers that *f* larger than 50 has not yet been determined in pulsating stars of comparable temperature and that Kurtz identified the pulsation modes of HD 101065 and HD 83368 as $l=1$ and 2 modes on the grounds of his oblique pulsator model. For us it seems that the only way out of the dilemma is to try to get high accuracy spectral line variations for the brightest pulsating CP2 stars and to use this information for an independent mode identification. A corresponding telescope time application is submitted to ESO.

This is the substance of the report of Dr. Hensberge, which was followed by a discussion from the ESO audience. The WG on CP2 stars then continued its work in one of the conference rooms of the ESO headquarters. This way the most recent results were discussed as well as the imminent observing runs and finally the individual applications for observing time for the next period. The next (spring) meeting of the WG will be held in Zürich or Paris.

The Working Group is very grateful to ESO for the hospitality shown once more. We hope that this time we could give the opportunity for some participation by preparing and presenting a report to the ESO public.

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Automatic Parameter Extraction for the 16,000 Galaxies in the ESO/Uppsala Catalogue

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Introduction

Since the completion of the ESO/Uppsala survey for southern galaxies last year a follow-up study of that survey has been prepared. The main purpose of the original survey was *to find and classify* galaxies on the ESO Quick Blue Survey (QBS). The copy plates were visually inspected and all parameters such as position, size and morphology were determined with the help of the human eye. A close inspection of the QBS down to the plate limit of ~ 21 mag would have revealed about 1 million galaxies. For the ESO survey it was decided to restrict the number of galaxies by including only those objects with an angular diameter larger than 1′. This limit roughly corresponds to the 15th magnitude and also had the advantage that the detected systems showed enough structure to classify them morphologically. 14,000 galaxies passed the angular size criterion and together with ~ 2,000 peculiar galaxies, ~ 1,000 star clusters and ~ 1,000 planetary nebulae they were brought together in a single volume (ESO/Uppsala Catalogue, A. Lauberts, 1982).

As soon as ESO initiated the new red survey on IIIa-F emulsion, plans developed to extract all possible photometric and morphological parameters from the complete set of B and R survey plates. At that time less than 10% of the ESO catalogue galaxies had published magnitudes and almost no red photometry existed for these objects. Detailed photometry was known for perhaps 100 of the brightest objects. Here we describe an extensive project that aims to calibrate both the R and B survey plates and to extract automatically both photometric and morphological parameters for all the galaxies present in the catalogue. A flow chart linking the different steps of the project is given in Fig. 1. Essentially the project contains the following parts:

1. Scan the 16,000 galaxies with the PDS on 606 Blue and 606 Red original ESO survey plates.
2. Bring together existing photometry in a catalogue and add complementary photometry using own measurements at the ESO 1 metre telescope.
3. Calibrate the plates and determine the properties of the galaxies automatically using the ESO VAX computers.
4. Produce a catalogue on paper, magnetic tape and possibly on video disk.
5. Investigate the data base scientifically.

By October 1983 over 600 plates, mostly in B colour, have been scanned, a preliminary catalogue of photometric standards has been compiled and satisfactory versions of the software are in operation on the VAX computers.

Below we give some more detailed information on the different steps and present some preliminary results of our test field No. 358, covering the Fornax cluster.

Digitizing the Plates

As soon as a plate is manually positioned in the PDS (emulsion up) and the machine is set to zero density at the plate fog level, the scanning procedure is fully under control by the