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History of CP stars

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Abstract. Some points of the history of CP stars are discussed.

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The early history of chemically peculiar stars is closely connected to the history of spectral classification, since the first peculiar stars were found and designated in the course of the Henry Draper Memorial classification work at Harvard, and therefore by Antonia Maury and Annie Cannon. The designation peculiar was first used by Maury. In 1897, Maury (under the direction of E.C. Pickering) published a detailed study of spectra of 681 bright stars in Volume 28 of the Annals of the Astronomical Observatory of the Harvard College, as part of the Henry Draper Memorial.

Maury was first assigned to this work in 1888. She alone was responsible for the classification of the spectra. She used the designation "peculiar" for the first time to describe spectral features in the remarks to the spectrum of α^2 CVn (Pickering, Maury 1897). The classification system adopted by Maury was different than that used before by Wilhelmina Fleming, and also from that developed by Annie Cannon later on, with which we are familiar with from the Henry Draper survey. She made a first attempt at a somehow two-dimensional classification system; she also considered the strength and the width of the spectral lines. Her remarks to the star were: *This star most nearly resembles those of Group VIII, Division a. It has, however, marked peculiarities. Thus, the line K is extremely faint, and the lines 4131.4 and 4128.5 have greater intensity than in any other stars except those of Division c in Group VIII. Some of the fainter lines appear to be peculiar in wavelength, while others differ in intensity from the corresponding lines of the stars in Division a. In the weakness of the line K alluded to, this star resembles those of composite type, and its peculiarities may perhaps be due to its known duplicity. If, however, in the companion star the line K is so faint, it is difficult to explain the absence of the Orion lines.*

There are two more stars classified by Maury to belong to the same group with the addition "peculiar" and nearly identical remarks: θ Aur and 81 UMa. We now know that both of them are true Ap stars.

It is obvious that with the term peculiar Maury describes features in the spectra of stars; it is used for all kinds of peculiarity. In the same descriptive way, Miss Cannon used the term peculiar in the Henry Draper Catalogue. And it is interesting to see in which way the meaning of peculiar was understood during the following decades. For example R.H. Curtiss in the 1932 edition of the "Handbuch der Astrophysik" extracted the following common characteristic features (Curtiss, 1932): *Peculiarities manifested themselves in five different ways: First the width of lines were found to be greater or less than normal. Second, notable departures from the relative line intensities of the typical star were present. A striking instance of this is found in the class A spectra with abnormally strong silicon lines of wavelength 4128 and 4131. Third, bright lines were present as in Class Md or in Classes O, B and A. Fourth, lines were found periodically double. Finally, spectra were found to be composite as in eta Carinae.*

In the 1958 edition of the "Handbuch der Physik" Philip C. Keenan made the remark (Keenan, 1958): *Any attempt to divide the stars into those having "normal" spectra and those having "peculiar" spectra must be arbitrary. As soon as we arrange stellar spectra into some sort of sequence, those which fit into the sequence (i.e., classification) defined by the majority automatically become "normal", while those which cannot be dropped into any of the normal classes are naturally called "peculiar". Some extreme cases will always be listed as peculiar just because there are very few similar spectra and it would serve no purpose to set up "classes" containing only one or two objects apiece*; and he gave some examples which made clear *that any definitions of peculiar stars are not only arbitrary but also subject to frequent changes.*

Finally W.P. Bidelman at the 1965 AAS-NASA Symposium, which was the first international meeting on chemically peculiar stars, stated (Bidelman, 1965): *The problem of the peculiar A stars and the metallic-line A stars is really twofold: stars of unusual spectrum are doing unusual things.* Knowing about the presence of magnetic fields, he could add: *There exist stars in whose spectra lines of certain elements are present in either unusually great strength or unusual weakness. ... These extraordinary line intensities are the only property shared by all of the objects. ... In many cases the magnetic fields are extremely strong. Many of the stars, but not all of those exhibiting peculiar spectra show periodic or near-periodic variations in many of their observable properties: in the intensity of the spectral lines, in light and colour, and in magnetic field. Rapid fluctuations in spectrum, light, and perhaps also magnetic field, have recently been observed.*

More powerful instruments, the improvement of observation techniques and the use of various analysis methods helped to achieve better knowledge about the objects, so nowadays it is possible to speak about "defining characteristics" of these stars.

Annie Cannon was the first to work on bright stars south of $-30°$ declination. She found some peculiar A stars having strong lines of ionised silicon or ionised strontium, a feature she used for splitting these stars into two groups (Pickering, Cannon 1901; Hearnshaw, 1986). The Si-stars had already been found by Maury in the northern hemisphere. Cannon also found objects with strong metallic and weak Ca lines - stars which after 1943 were classified as Am stars.

Meanwhile other spectroscopic work was done: by Sir Norman Lockyer and Frank E. Baxandell at the South Kensington Solar Physics Observatory, who found “strange lines”; by Hans Ludendorf in Potsdam (intensity variations); by Belopolsky at Pulkowo (periodicity); and the first photoelectric photometry was carried out by Guthnick and Prager at Babelsberg. Through those investigations, some of the principal properties of these peculiar stars had been established: spectrum and light variability, the sharpness of the lines and the enhancement of some elements.

The photometry of α^2 CVn by Guthnick and Prager (1914) was part of the first photoelectric observations at the newly built Babelsberg Observatory with a 30 cm refracting telescope. The title is “Photoelectric observations of spectroscopic double stars and planets”. It was the first publication dealing with measurements done at Babelsberg, therefore the major part of the publication describes the instrumental equipment and the reduction techniques. α^2 CVn was one of the observed objects; it was selected because of its peculiar spectrum. The remarkably accurate light curve with an amplitude of only a few hundredth of a magnitude leads to the same period of approximately five and a half days as the spectroscopic observations by other authors. (The photometer used at that time now is in a section of the Deutsches Museum in Munich.) Guthnick later on became director of the Babelsberg observatory.

One may conclude that main properties of these objects were already known at the beginning of the 20th century.

In the course of the production of the Henry Draper Catalogue, Cannon also found spectra with weak Ca lines but strong metallic lines. Those stars were investigated in 1953 by Arne Slettebak for stellar rotation (Slettebak, 1953). Among them were several Ap and Am stars.

The Henry Draper Catalogue contains 165 stars with a spectral type between B0 and F0 marked with a “p” as peculiar, the majority of them are A0p or A2p. In 1916/17 Carl C. Kiess from the University of Michigan made a detailed study of the line identifications and wavelength (Kiess, 1917). He was able to add yttrium and some rare earth elements and, confirmed the periodicity of radial velocity and (for some lines) intensity variations. But no one could explain the abnormal strength of some lines. Shapley in 1924 stated that abnormalities in abundance are possible, but Miss Payne did not believe that (Hearnshaw, 1986).

From 1931 to 1935 W.W. Morgan studied some Ap stars, α And and 13 other manganese stars. In BD$-18°3789$ he found strong lines of ionised chromium with periodic variations in antiphase to the europium lines, and he found some more europium stars. He also found some chromium stars such as ι Cas and 17 Com. In 73 Dra he detected variable intensity of europium lines with a period of 20.7 days. In 1933 he correlated abundance anomalies with the ionisation temperature and defined five groups of peculiar A stars, with quite a lot of overlapping and the silicon stars occurring in the first three groups (Hearnshaw, 1986):

– Mn II stars (α And and μ Lep)

– Stars with the (at that time unidentified) $\lambda\,4200$ (θ Aur); identified by Bidelman in 1962, as a blend of two high excitation ionised silicon lines

– Eu II stars (α^2 CVn)

– Cr II stars (73 Dra)

– Sr II stars (γ Equ)

Because of the individual differences between stars of the same spectral type he stated: *From the foregoing discussion it seems safe to conclude that there is some physical factor other than temperature and surface gravity concerned in the production of spectra of the A stars and that the additional factor is probably variable effective abundance in a number of elements observed, if not in all of them.* This additional factor was found by Horace W. Babcock in 1946.

I want to include a part of George O. Abells speech on the occasion of the award of the Bruce Gold Medal to Babcock in 1969 by the Astronomical Society of the Pacific (Abell, 1969): *By far the most important of Dr. Babcocks contributions have been in the field of extraterrestrial magnetism. F.H. Bigelow had speculated on the existence of a solar magnetic field 70 years ago, and actual measurements of the Zeeman effect, revealing strong magnetic fields in sunspots, were made early in the 20th century. The existence of a general magnetic field of the sun, however, was still debated as late as 1950, when the senior Babcock showed that if such a field exists at all it is less than 1 or 2 gauss. The first definite evidence of a weak general solar field was provided in 1952 by the two Babcocks . . .*

A general magnetic field, like the suns, would be impossible to detect (with existing techniques) on other stars. Several investigators speculated that stronger stellar magnetic fields that could be observed might exist, nevertheless, and searches were made for such magnetic stars. All were in vain, however, until 1946 when Babcock employed his improved polarizing analyzer with the spectrograph, and with it he detected the Zeeman effect in the spectrum of the star 78 Virginis, indicating a magnetic field on that star of about 1500 gauss. Subsequently he investigated other stars and discovered that a number of peculiar A-type stars, whose spectra show periodic variations, have strong magnetic fields that also vary in phase with the spectral changes.

Babcock (1958) published a catalogue of magnetic stars, 89 stars show a definite magnetic field, 66 stars have probably a magnetic field, 60 stars with sharp lines show no magnetic field and in 120 stars the lines were too broad for the detection of a magnetic field. Magnetic variability was recognized as a general feature.

Otto Struve stated in 1950 that the discovery of stellar magnetic fields was *the most significant advance in this field.*

The first astronomical meeting I attended was the meeting of the Astronomische Gesellschaft 1966 in Göttingen. At that meeting Lore Oetken from Potsdam gave a review talk on magnetic stars: she reviewed all the methods of observation used at that time, their results, and the models discussed at that time (the oblique rotator, Babcock 1949, specialised by A. Deutsch; the magnetic oscillator and its specialisation, the sunspot model; the double star model), she spoke about the origin of the magnetic field, and she concluded with a list of (at that time) unsolved problems (Oetken, 1966).

Most noticeable is the list of references she gave: only a few authors she mentioned did come from Europe; one of them was Karl Rakos, who at that time was at Lowell Observatory. Personally, I conclude that at least one of the members of the Vorstand (Board of Directors) of the Astronomische Gesellschaft, which was responsible for the invitation of the speakers of the Reviews, was convinced of the growing importance of magnetic stars; I think it was Friedrich Wilhelm Jäger, who was director of the Einstein-Turm in Potsdam for several years and did work on solar magnetic fields. It seems that from that time on, astronomers in Europe started to work in that field. For example, in 1975 in Vienna IAU Colloquium No. 32 on the Physics of Ap-Stars was held, and in 1978 the European Working Group on CP stars was founded.

I just want to mention two other important contributions. All investigations in the field of chemically peculiar stars have been done by spectroscopic means. H.M. Maitzen (1976) introduced a narrow band three filter photometric system for the investigation of the flux depression at 5200 Å, the tool of Δa-photometry which enables classification observations of substantially larger distances than by spectroscopy. G.W. Preston (1974) proposed the division of CP stars into four groups from CP1 to CP4:

CP1 : Am/Fm stars without a strong global magnetic field

CP2 : Ap stars with strong magnetic fields

CP3 : HgMn stars, most of them not magnetic

CP4 : He-weak, some with a detectable magnetic field

More detailed reviews on the history of CP stars are given by Sidney C. Wolff (1983) and J.B. Hearnshaw (1986).

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