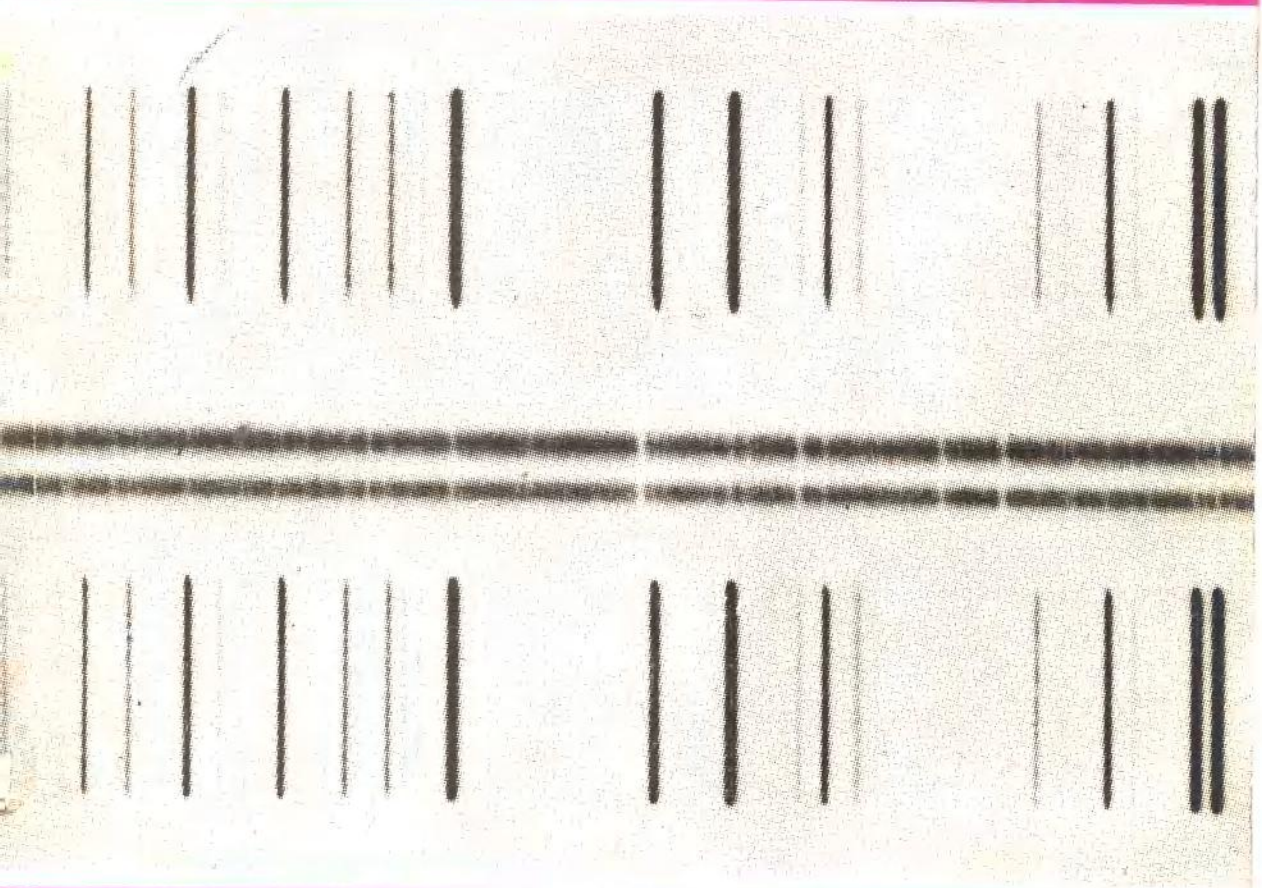
PHYSICS OF Ap-STARS



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PHYSICS OF Ap – STARS

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FOREWORD

A decade has passed since the last international conference on Ap stars took place in Greenbelt, Maryland, USA. Meanwhile, our knowledge of the physics of Ap stars has increased considerably: some problems could be solved, but even more have arisen because of improved observing techniques and new theoretical calculations. It was therefore desirable to organize again an international conference on Ap star physics and to produce a report on the status of this field.

Since it was 100 years ago that the Vienna Observatory was moved from the city to the countryside and equipped with the (then) world's largest telescope, we found it appropriate to celebrate the centennial with a conference on one of the main present-day research activities at the Vienna Observatory. This idea also found approval with officials of the International Astronomical Union. We would like to take this opportunity to express our gratitude for their support. We must also thank the Scientific Organizing Committee for their help:
F.Catalano, M.Hack (chairman), C.Jaschek, V.Khokhlova, L.Mestel, K.Osawa, G.Preston, K.Rakosch, A.Slettebak, E.van den Heuvel and S.Wolff.

Prof. J. Meurers, Director of the Vienna Observatory, has always been an encouraging promotor: in the time of preparing the meeting as well as in the months while these proceedings have been edited.

Prof. P. Weinzierl, Director of the 1. Physikalisches Institut, acted as a host to this colloquium. He and the members of his institute made the conference pleasant and productive for all the participants.

In a time, in which finances for astronomy are on the decrease, we have been lucky to find sponsors, who supported us with money or material:
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Last but not least we have to mention the Local Organizing Committee, which was involved in most of the work connected to this colloquium: H.Fischer, H.Jenkner, W.Weiss (chairman), R.Wewerka and students from the Institute for Astronomy: E.Fotter,

D.Oberlerchner, A.Schermann and W.Zahradnik. Miss M.Kirchmayr typed the complete proceedings with an Olivetti tape editor machine and sacrificed countless hours of her spare time.

We finally would like to thank all the authors, who have contributed to this volume.

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W.W. Weiss
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Editors

Vienna, August 1976

WELCOME BY PROF. J. MEURERS

Ladies and Gentlemen,

I have the honour as Director of the Vienna Observatory with Leopold Figl-Observatory for Astrophysics, to greet you and to welcome you to Vienna.

That you came, and came in such large numbers, is an important acknowledgement for the scientific work of my staff colleagues who are working in problems of Magnetic Stars. The staff of a modern astronomical observatory must be, so to say, a republic of scientists with as much freedom as possible. So I am very glad, that the circle, working here in Magnetic Stars, could be so successful, that the International Astronomical Union looks to Vienna as a base for such a colloquium. It is the first meeting in Vienna, sponsored by the International Astronomical Union. I wish to thank Prof.M.Hack, Chairman of the Scientific Organizing Committee, for her help and support in organizing this meeting. I must also thank Dr. Weiss for his indefatigable efforts during the preparations of this meeting here in Vienna. He contributed not only to the immediate organization but also to the ideas and intellectual design of the programme.

Magnetic stars are perhaps one of the most interesting and fruitful objects of astrophysical research work today. There are two reasons for this: recent advances in the technology of instrumentation make tests of theory increasingly precise, and secondly, growing interaction with other fields of physics and astronomy has, of late, contributed to Ap star work. And thus, we hope through this meeting on a specific topic, you will be able to contribute to the whole of astronomy.

As you may know, this meeting is held in connection with the 100th anniversary celebration of the old University Observatory in Vienna on the Türkenschanze, and I want to personnally invite each of you to visit the Observatory as soon as it is possible for you. I wish you a fruitful exchange of ideas and a productive meeting. Thank you.

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OPEN DISCUSSIONS

Ap-STAR MODELS

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PHENOMENOLOGY

The outstanding observational facts that impress the theorist studying the magnetic Ap stars are as follows:

1) The very strong, large-scale magnetic fields, inferred from the integrated Zeeman effect. Typical polar fields are 10^3 - 10^4 gauss, the strongest known being $\approx 3.5 \times 10^4$ gauss.
2) The variability of the fields, spectra and luminosities, with the fields often reversing in sign. Typical periods are 5 - 9 days, but periods shorter and very much longer are found, with a small group of stars having periods of several years.
3) The low rotations of most Ap and apparently all known Am stars, compared with normal A stars. The possibility that we are seeing normal A stars pole-on seems statistically untenable.
4) The "cross-over effect" (Babcock 1956). This describes how the difference in the widths of two circularly polarized Zeeman components of a spectral line becomes particularly large at the phase when the net field becomes small.

The <u>oblique rotator</u> (Stibbs 1950; Deutsch, in Lehnert 1958, p. 209; Deutsch 1970; Preston 1967) is a simple and attractive phenomenological model which has shown itself flexible enough to accomodate much of the observational detail that has accumulated. The basic feature is that the variation in surface field etc. is due to the rotation of a quasi-rigid, non-axisymmetric structure. The (comparatively) long periods of variation are then confirmation of the abnormally low angular velocities. In the simplest version of the model the field is taken as symmetric about an axis $\vec{p}$ inclined at an angle β to the rotation axis, and with the radial field component antisymmetric about an equator which passes through the star's centre of mass. This is the model we shall have primarily in mind; however, we should remember that the observations may be describable in terms analogous to the part of the solar field with a sector structure

- a field that is essentially non-symmetric about an axis identical with the rotation axis (Wilcox et al. 1969). The fact that the Zeeman curves are not antisymmetric with respect to a half-period can be incorporated (Landstreet 1970) by displacing the dipole from the star's centre along the axis (a device that may yet prove fruitful in pulsar theory for understanding the absence of interpulses of the same strength as the main pulse). Likewise we anticipate that the consequent mild asymmetry with respect to the magnetic equator can explain why the observed small light variations do not have a period of variation equal to just half the magnetic period. The cross-over effect also receives a simple and natural explanation (Babcock 1956; Hockey 1971).

Particularly impressive is the evidence for self-consistency accumulated by Preston (1971), following earlier work by Deutsch (in Lehnert 1958 p. 209) and recently confirmed by the Jaschecks (this volume). The observed magnetic and spectral periods are plotted against spectroscopically-determined v.sin i, i being as usual the inclination of the rotation axis to the line of sight. The points all lie below a rectangular hyperbola defined by $i = 90^o$, as expected. Preston's original tentative conclusion that this envelope requires an average Ap star radius approximately twice that of a zero-age, main sequence, normal A star is now considered doubtful by Preston himself (private communication) and is contested by Stift (1974).

In another study Preston had concluded that the angle of inclination ß between the magnetic and rotation axes is not random, but shows a marked preference to be near 90^o or near zero. Borra (1974) argued that Preston's small ß cases could in fact again have large ß and in addition a large equatorial asymmetry. However, Landstreet (this volume) has recently confirmed the existence of at least one small ß case.

There was for a while a tendency for theorists to treat all the Ap stars as a homogeneous group coextensive with the class of stars with strong surface magnetic fields. However, there is now ample evidence against this. The Wolffs (this volume) argue for two essentially continuous sequences of peculiar stars with main sequence luminosities and with surface temperatures between 7000 K and something over 20,000 K. The strongly magnetic stars are found to be at least a sub-set of (and possibly coextensive with) the Si-Cr-Eu-Sr group among the Ap stars. The second sequence, with no observable magnetic fields, comprise in order of increasing temperature the metallic-line (Am) stars, the Hg Mn group of the Ap stars, the He-weak and the He-rich stars. Slow rotation appears to be a necessary condition for this sequence (though we recall Deutsch's conclusion (Cameron 1967, p.181) that there is a group of AO stars with both slow rotation and normal surface composition).

This report is concerned primarily with the theoretical problems set by the magnetic Ap stars. However, from the start we do not restrict our considerations to stars which are observably magnetic, and not only because magnetic fields can still be dynamically significant over stellar lifetimes while too weak to be optically observable. We want to know the origin of the fields of magnetic stars, and to give physical reasons for e.g. the non-random distribution of angles β. But equally we want to know why there are any normal, rapidly rotating A stars at all, and what distinguishes the two sequences of peculiar stars. An adequate theory should also explain why there are apparently no late-type strongly magnetic stars.

In my view, the most significant generalization that we can make from the observational material is the broad anticorrelation between angular velocity Ω and the strength of the surface field, as measured by the flux F_s across a hemisphere. We have already remarked on the gross anticorrelation, with the class of observably magnetic stars having usually significantly slower rotations than normal A-stars. There is now evidence reported by Landstreet (this volume) and the Wolffs (private communication) of such a correlation within the class of magnetic stars itself, in that strong fields ($> 10^3$ gauss) seem significantly less common among the more rapidly rotating Ap stars (v.sin i > 30 km/sec). Such results are by their nature only statistical, if only because of the presence of the factor sin i. And if we accept that the period of variation is a rotation period, then there are certainly exceptions: as pointed out by Cowling (in Lüst 1965), one finds stars with similar colours, spectra and Zeeman curves, yet differing in periods by a factor ten.