# SUMMARY – A PERSONAL VIEW

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Let me first remind you of the subject of the present Joint Discussion. It is about spectroscopy with large telescopes. As I have never done any spectroscopic research of my own and I have never observed with a very large telescope, I am certainly the right person to summarize the most recent results in this area.

There exists a notion called the Anthropy Principle. It deals with a relation between the Universe with its physics laws and constants, and Man – its conscious observer. The strong version of the Anthropy Principle says that the Universe was made in such a way as to enable a very high degree of the matter organization up to the bringing intelligent life into being. In other words, the whole Universe, with its complex structure and evolution, was made especially for its observers. I have been attending conferences on CP stars for the last 30 years. Observing how enthusiastic students of CP stars are, and how much fun they have discovering new aspects of physical phenomena going on in these objects, I cannot resist an impression that the Strong Anthropic Principle is correct after all, at least in a part related to CP stars. It seems true to me that CP stars have indeed been formed to amuse astronomers and give them pleasure (I wonder what would Don Kurtz do if ro Ap stars did not exist?).

Whatever the philosophical cause of their origin, CP stars are reality which we observe, investigate and try to understand. Research on CP stars can be roughly divided into two broad categories:

*i)* "static" approach in which instantaneous observations are interpreted using static models, i.e. ones which do not contain time dependence,

*ii)* "time variable" approach in which dynamical, or time dependent phenomena are observed, interpreted and modeled.

The determination of the basic global parameters belongs to the first category. Several statistical methods, based on photometry and spectrophotometry, have been developed to determine accurate values of effective temperatures and gravitational accelerations of CP stars whereas data from Hipparcos made possible the accurate determination of their absolute magnitudes. The knowledge of the basic parameters seems to be at present reasonably good for a large sample of the stars. As the results show, CP stars occupy more or less uniformly the whole main sequence band above a mass of about 1.5 $M_{\odot}$, although the distribution of magnetic stars may deviate from this simple picture. One should not, however, forget about realistic errors of the parameters. As Michele Gerbaldi demonstrated, temperatures of even perfectly normal A0V stars cannot be determined to an accuracy better than about 200 K by statistical methods. Errors on temperatures of CP stars are very likely still larger.

Regarding other global parameters, the recently published results on $v \sin i$ values of Ap stars confirmed their slower rotation by a factor of about 3. A conjecture has been put forward that a slow rotation is not only necessary but also a sufficient condition for a star to become chemically peculiar. The old hypothesis that the magnetic field observed in several CP stars is of primordial origin received an additional support from recent evolutionary models of pre-MS stars of an intermediate mass. The models indicate that such stars never go through a fully convective phase, hence any pre-existing magnetic field has a good chance to survive the pre-MS evolution and show up on the MS. G. Mathys presented the observations of magnetically resolved line profiles of more than 20 magnetic stars. The distribution of intensity of the surface magnetic field shows an unexpected cut-off value: no field weaker than 1.8 kG has been so far observed although the error of measurements is definitely lower than this.



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Apart from a significant progress in our knowledge of the global parameters of CP stars, we still have several unanswered questions regarding their global properties. Why some stars are born with kiloGauss fields and others with none (at least to the limits of observational accuracy)? A sensitive search for magnetic fields among Herbig Ae/Be could clarify the situation. What is the mechanism of angular momentum (AM) loss of CP stars? Quantitative models of the pre-MS evolution including possible mechanisms of AM loss of these stars would be very useful. What happens to chemical peculiarities and magnetic fields when a CP star leaves the MS? The present observational data suggest that none of the known CP stars lies unambiguously within the Hertzsprung gap. Is this a selection effect or these stars really lose peculiarities right beyond the MS? Will a strong magnetic fields survive up to the giant branch, and if yes, what will be its observational signature?

A remarkable progress has been made in modeling of CP star atmospheres. A dense grid of LTE models with various chemical compositions is now existing thanks to continuous effort of Robert Kurucz. In addition, he made the special software available for computing a model atmosphere of a star with chemical abundances set individually (ATLAS 12). The number of lines included into his models becomes truly astronomical and it increases constantly at a high rate due to an enormous increase in our knowledge (and availability, thanks to development of modern data bases) of atomic data.

NLTE effects are known to play an important role in forming the emergent energy distribution of CP stars, particularly in UV. This is due to a modification of a temperature structure of atmospheric layers. However, as shown to us by Ivan Hubeny, one must be very careful in comparing observations with models: insufficient, or inaccurate atomic data may result in LTE features mimicking NLTE effects.

High resolution spectra with an unprecedented quality are now becoming available, both from HST and ground based telescopes. Profiles of intensity and polarization of spectral lines of a CP star contain information on the 3D distribution of elements, on the detailed structure of the magnetic field (including its non potential part), velocity field within the atmosphere and physical processes taking place in the outer layers of the star. It is a great challenge to extract and to use fully this information. We are learning quickly how to do it, and the results of such detailed modeling are being published, but even more improved models, making use of simultaneous observations obtained with different techniques, are urgently needed.

The case of $\chi$ Lupi, presented to us by David Leckrone, needs a special notice; a huge international effort of a team of several people, working both on observations and theory for several years, resulted in a very high accuracy of data on chemical composition of this star, atomic spectroscopy, a large number of new, precise atomic data, quantitative constraints to the diffusion theory, and several other impressive results. It is rather improbable that the science financing institutions would accept such a high cost of studying in the same way several other CP stars. We may only hope that the experience gained during this pioneer study will profit in a greatly increased efficiency when investigating equally thoroughly next CP stars. By the way: one may wonder, why $\chi$ Lup? There exist other similar, sharp lined stars suitable for such a study. I guess, the explanation lies in the abundance diagram of $\chi$ Lup shown to us by David. One can notice that the star contains huge excesses of platinum and gold. I suspect, David plans to lay hands on that.

To improve atmospheric modeling we need, apart from the more accurate atomic data (the need which will never be fully satisfied), a better information on the detailed structure of the atmospheric magnetic field. A "standard" model atmosphere assumes a passive, potential field. There exist, however, observational indications that the field may deviate from a force-free configuration, which would result in the presence of the Lorentz force modifying the structure of the atmosphere and possibly leading to the solar activity-like phenomena. Lorentz forces produce predictable observational phenomena, discussed nearly 20 years ago by the present author and his collaborators, but at that time a non potential part of the field could be treated only as a free parameter.

Regarding the investigation of the "time variable" phenomena in CP stars, we gained recently a lot of new insight into the phenomenon of pulsations of ro Ap stars. The subject was covered in a great detail by the *IAU Symposium* No. 185 and summarized very neatly here by Jaymie Matthews and Don Kurtz. The newest, very interesting result is connected with a secular (i.e. having a time scale of years) variability of pulsation frequency observed in some ro Ap stars. Are we witnessing a chaotic behavior of the underlying phenomena?

Georges Michaud and his collaborators presented new, self consistent results of the diffusion modeling. The newest opacity tables were included and the evolution of abundances of nearly 30 elements was monitored through the large part of the stellar life. It was demonstrated that diffusion is not just a sort of a higher order process going on with a negligible back reaction on the basic structure of the outer layers of a star but, instead, it can substantially change the opacity. That results in a significant modification of the structure of these layers, in particular of the radiation field existing in them and, perhaps more important, of the extend of convection. Similar results were obtained by Dr. M.J. Seaton.

While the identification of different pulsation modes in ro Ap stars seems now quite secure, their excitation mechanism is still obscure.These stars may well have convection layers containing enough kinetic energy to disturb magnetic fields permeating them and to produce a significant nonthermal energy flux heating the upper atmosphere. A sharp increase of temperature provides a reflective "wall" for pulsational disturbances, which produces standing waves. If the temperature increase is large enough it may cause a loss of matter via a thermal stellar wind. Development of expected observational diagnostics for the temperature increase and the thermal stellar wind would be particularly useful. Detection of IQ Aur in X-rays, reported by Jaques Babel, is extremely interesting in this respect but the existence of hot coronae or other X-ray sources in CP stars needs a confirmation. Another possible mechanism of the mass loss in CP stars is via a radiatively driven wind. Standard solutions for hot CP stars give a large mass loss difficult to reconcile with the diffusion theory. The calculations carried out by Jaques Babel show that shadowing by photospheric lines may decrease significantly the efficiency of the wind in several stars. So far, the mass loss rate is a free parameter in the diffusion theory. Constraints on its value would serve as an important test for this theory.

Long time variations of photometric and spectroscopic properties of several CP stars had been reported in fifties and sixties. When the more accurate observations did not confirm this variability, a static picture of a CP star became a paradigm, in which the only observed variations were due to rotation (plus rapid oscillations in some of them). Recent results on long time variations of pulsation frequencies as well as reports in literature on possible variations of photometric curves of some variable CP stars suggest that the time might have come to revise this paradigm and to start a sensitive search for secular variations in the observed phenomena.

One way of doing progress in science is to pick up an apparently strange coincidence in the observed data and to explain it in terms of a causal relation. Let me therefore finish my talk with an advice borrowed from Miss Marple: "Any coincidence ... is always worth noticing. You can throw it away later if it is only a coincidence" (Agatha Christie).