GROSS STRUCTURAL PATTERN FOR THE ATMOSPHERES OF Be, AND SOME CLOSELY RELATED, STARS

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Summary : Abstracted comparison of Struve's 1942 quasi-empirical model of the shell-atmosphere of Be and similar stars, based on visual data and quasi-radiative equilibrium, to that demanded by current visual+nonvisual data, requiring nonradiative+mass fluxes characterized by variability and individuality.

In 1941-3, Edlen's identification of the superionized coronal lines, and Redman's demonstration of the mass-dependence of chromospheric linewidths, destroyed RE modeling for the observed extended-atmosphere of the Sun. Just then, Struve (1942) abstracted existing visual-spectral observations of a variety of hot stars, mainly peculiar, with prototype the Be, into a universal, ad hoc, cool-structured pattern of their inferred extended-atmospheres, then called "shells". The observed visual subionization, relative to photosphere, implied the cool, hence quasi-RE but not He, shell. The 3-phase behavior of Be stars suggested variability for some shell properties. Observation of displaced, sometimes multiple, line-components in a variety of stars suggested that the shell could have multiple regions, some of which moved, differentially. Struve proposed a two-region structure, by analogy with the pre-1942, RE, "solar-shell": a lower, quasi-static region, the "chromosphere" ; an upper, differentially-expanding region, the corona. Such shells differed from star to star, even from sg to MS, not in their structural pattern, just in their visual continuous opacities. The shell-regions merged continuously with those above and below ; there were no nonradial asymmetries in opacity, no opaque areas adjacent to one where the photosphere could be seen. Struve conjectured that all hot stars, not only peculiar ones like Be and Sun, had such extended-atmospheres at some phases ; thus that the ability to produce such a pattern was a rigid test of the capacity of modern atmospheric modeling. He further emphasized that it was premature, at that epoch, to speculate on the cause of such extended-atmospheric pattern until it was established, observationally, what modifications must be made in the proposed pattern. While he suggested a rotationally-unstable mass-ejection might, in some stars, be one possible cause, he subordinated its general importance. Those rough estimates he made of

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theoretical ejection-velocity focused on radiative-acceleration ;hence, his spherically-symmetric model.

At this epoch, we are better-equiped than was Struve to ask for modifications in his proposed pattern, from the farUV, x-ray, farIR, radio and more high-resolution visual observations. Ours is also similar to the 1942 epoch, in that now the hot-star shell, as then the solar-shell, cannot be forced into an RE pattern ; and we try to decide between nonRE but thermal extension, and nonHE nonthermal extension to represent the atmospheric density gradient : empirically, not speculatively. So we summarize the change in Struve's shell-pattern suggested by modern data, especially nonvisual, but still emphasizing the equal importance of the visual, subionization data to the farUV, superionization data in giving the complete extended-atmospheric pattern. At Struve's epoch, the sub-ionized data characterized the whole shell ; at our epoch, only the post-coronal, cool decelerated outermost shell regions. Then, the only super-ionized data were on WR symbiotic, novae, etc "similar-to-Be" stars ; now, they are universal ; and they refer to the inner shell regions. We still focus on the "Be+similar" stars, and on the striking thermodynamic change for these stars, as for the 1942-Sun, being the universal observational-existance of nonradiative-energy and mass fluxes instead of their pre-1942 speculative-exclusion.

We summarize the changes in Struve's shell-structural pattern by region, identifying the data suggesting such change. Details, and references, will appear in Underhill and Doazan (1981), Hack and Stalio (1982), Thomas (1982).

Struve's solar-analogy chromosphere had 2 roles : (1) provide that continuous, thermal (quasi-static) transition from the photosphere which preserved high-enough shell-densities to produce the observed Balmer-line emission : (2) to produce sufficient cooling from photospheric T_e to permit FeII absorption lines of the observed strength, (1) and (2) being capable of time-variation. Role (1) is now replaced by that of a hot chromosphere, with RE failing at a maximum height, and minimum density, fixed by the observed size of the mass-flux. For F_M of 10^{-5}-10^{-9} ; log=4; $R=10R_\odot$; T=25,000K ; these minimal densities correspond to particle concentrations $3(10^{13}-10^{9})$. Given a concentration 4.10^{14} at $\tau_5 \sim 1$, nonradiative heating starts no more than 2-10 density scale-heights, or 0.0008-0.004 radii, above $\tau_5 \sim 1$. Thus the post-1942, hot chromosphere,begins low. The nonradiative energy flux,which is demanded by the observed super-ionization, can only decrease these beginning heights ; and it is its properties, unfortunately not known other than speculatively,which fix the outward increase of Te. The only data give a lower limit on the T_e(max) somewhere above these minimal heights : some $x.10^6$ (x>1) : from x-ray and the superionization observations. Role (2) of Struve's 1942 chromosphere is, in 1981, transferred to a post-1942 post-corona, where expansion velocities $\lesssim$100km/s and FeII exist.

Struve's solar-analogy corona had 2 roles : (1) to move,differentially, at velocities up to $\gtrsim$ 150km/s, sufficient to produce either or both of strongly-displaced absorption lines and P Cyg profiles ; (2) maintain sufficiently-large densities that such profiles (1) can be observed ; (3) have sufficient range of excitation/ionization to produce lines from HeII to FeII but to remain "cool". Role (1) is now expanded to permit V up to 2-3000km/s. The densities of Role (2) are maintained by a combination of thermal, HE suport as T_e increase from T_{eo} (RE, HE) up through $x.10^6$ (x>1) ; giving way to the nonthermal support corresponding to the velocity-distribution of (1) ; with the transition-height from thermal to nonthermal support being highly individualistic, fixed by a combination of (T_e,g,rotation,mass-flux,radiative-acceleration) effects. Role (3), expanded to include lines from FeII through solar-coronal ions and soft x-rays, unrestricted to being RE and cool, is now divided between 3 regions : the post-1942 hot corona, containing T_e (max), and two post-coronal regions of lesser T_e.

The post-Struve, post-coronal, modern Stromgren HII region has 2 functions : (1) to cool the coronal gas to values where the HII-HI transition occurs ; (2) to decelerate the gas to $V \lesssim 100$km/s relative to the photosphere. To accomplish these functions, the gas must cool, radiatively outwards except for a rise and fall at the shock-front necessary to decelerate the wind to the $V \lesssim 100$km/s observed in FeII and H. Note that a lower-limit on the pre-deceleration wind-velocity is the coronal thermal velocity. Note that the properties of this modern Stromgren HII region are not fixed by the RE photospheric radiation field, as was the classical one, but by the properties of the combined, nonradiatively-heated, hot chromosphere-corona, plus those of the wind. Further, note that the decelerating medium cannot be the normal ISM, which would decelerate in distances ~ psc, because of the visual, farIR, and radio data which fix maximum radii of this HII region ~100 photospheric radii. One recalls McLaughlin's characterization of Be stars as "little planetary nebulae". Then, note that the mass-flux variability shown by Be stars, and the idea that one requires a variable mass-flux to produce a planetary nebula (Kwok, et al, 1978) accord in this picture. For empirical modeling of these low-density regions, one must depend heavily on data from the Bep, and symbiotic stars which show both forbidden lines of varying ionization and the largest IR and radio excesses.

The post-Struve, post-coronal, HI region is subject to debate as to whether the gas alone ---from all the interior regions, hot and cool--- suffices to produce the IR and radio data, or whether dust regions are also necessary. Again, it is the Bep and symbiotic stars, among the "Be and similar" star group which provide the most information. At present, we do not have sufficient data to say much except that these regions, for at least some stars, extend out some 10^3 photospheric radii.

We present several slides and calculations illustrating characteristics of the proposed pattern, which there is not enough space to reproduce in this summary.

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