VARIABILITY IN β CEPHEI AND B STARS

Myron A. Smith
Department of Astronomy
University of Texas at Austin

1. The Period Range of Variable B Stars.

Rather than review β Cepheids, this paper will address the issue that β Cephei variability is only a readily detectable tip of a much larger iceberg of variability among B stars. This variability being widespread, it becomes crucial to differentiate β Cepheids from other variable subgroups by observational criteria if one is ever to make physical inferences concerning the instability mechanism involved. Shobbrook (1978) has raised this point indirectly in discussing the importance of defining the width of the instability strip: if the strip is narrow, the pulsational instability is more likely to arise in the stellar core; if it is wide, it is probably excited in the envelope. Enormous efforts have gone into delineating the evolutionary and HR-D confines of β Cepheids. In this paper it will be suggested that the situation is more complicated than the traditional outlook holds.

Consider first the discovery of the 53 Persei variables (PP62, S77), which I believe to be the spectroscopic analogues of many of the "ellipsoidal variables" that have long plagued β Cepheid workers. These 09 to B5 stars show often significant periodic changes in line profile widths and asymmetry, small changes in light, and just detectable changes in color and radial velocity. 53 Per variables surround the β Cepheids on all four sides in the HR-D and may include some supergiants. Their periods are unstable, but are usually recurrent, and favor period ratios of two. There are several reasons (S79) for believing that these stars are sectorial-mode nonradial pulsators (NRPs). If current theory is correct, their usually long periods imply the dominance of high-overtone g-modes.

On the opposite side of the period spectrum comes the recent photometric discovery of the ultrashort period variables (USPVs; J79), a group of four B2 to B3, IV to V, stars exhibiting periods of 1/2 to 1 hour. A few additional reports (E79) also hint at some B stars having "short" periods of 1 to 3-1/2 hours. Warman reports that ι Her, a 53 Per-type, showed P ≈ 1.4 hrs. on one occasion. In no one case is the evidence for periodicity compelling yet, but altogether a strong case emerges for

Patrick A. Wayman (ed.), Highlights of Astronomy, Vol. 5, 457–460.

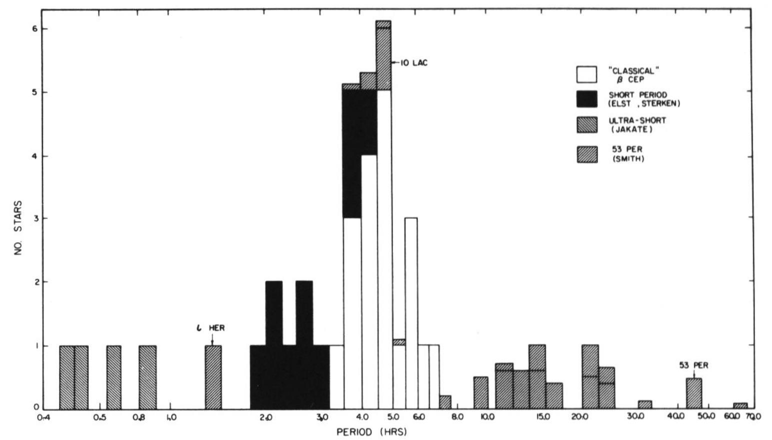

Fig. 1 - Periods of representative β Cepheids, 53 Per, and USP variables.

small amplitude, short-time-scale variability occurring often in some early B stars. Preliminary evidence indicates that the oscillations in ι Her (possibly also twice observed in 53 Per) are transient, whereas the periods of the USPVs may be stable (Jakate, priv. comm.).

Figure 1 shows a global picture of pulsation in B stars, a period histogram that includes "classical β Cepheids," (MP75), 53 Per variables (S79), and USPVs (J79, E79). The β Cepheid sample chosen is probably representative but it is not extensive. The figure shows that the period range that can be excited in B stars exceeds 100 and that the β Cepheids are centered in the log P distribution. A possible interpretation of the distribution is as follows: β Cepheids pulsate in low-overtone radial or nonradial modes, whereas the two extended distributions represent high-overtone p- and g-modes; the quasi-flat distributions mean that each high overtone has nearly an equal chance of being excited. Additionally, the apparent coexistence of long and short periods in a star (e.g. ι Her) suggests, as in the Sun, that the fundamental source of instability is the same even for widely disparate modes. In this picture all subgroups would have the same underlying nonradial instability, which under proper conditions drives a more readily observable radial mode in β Cepheids.

2. What is a β Cephei Star?

If these subgroups can be associated with discrete mode-types, it makes sense to find observational criteria to differentiate them. Most β Cephei reviews have skirted a β Cephei definition, perhaps justifiably at those times. However, various reviewers are unable to agree even on the period limits for the class. In view of blurring of the subgroups in Fig. 1, it is now essential to make a sage definition of a β Cephei star; I hereby make this challenge to veteran workers. My contribution follows in § 4. In the meantime let us list oft-cited observational "characteristics" that alone, or even taken together, are inadequate to separate the subgroups, or must be arbitrarily defined to do so:

1.) HR-D position -- The USP and 53 Per variables run contiguous to the β Cepheids. Hence this criterion alone is arbitrary.

2.) Periods -- At least four 53 Per variables have exhibited periods of 3.6 to 7.3 hours at various times (S79), so they overlap with β Cep periods. Moreover, from Fig. 1 any period limit appears arbitrary.

3.) Period or amplitude stability -- 10 Lac (53 Per-type) may exhibit a stable line profile period of 4.9 hours, but its O8-O9 spectral type would preclude its β Cepheid membership according to the usual B0.5 to B2 rule. Finally, the amplitude of one β Cepheid (α Vir) is known to have changed over a few years (L78).

4.) Line profile variations -- Because of its slow rotation rate γ Peg (β Cep-type) does not show profile variations (excepting shell features, SM78). Many other β Cepheids do, as of course do the 53 Per variables.

3. Toward Modal Identifications in β Cepheids: Radial or Nonradial?

There are several spectroscopic and photometric reasons for believing that 53 Per variables are NRPs. Accordingly, they offer valuable mode-typing criteria to compare in the β Cepheids. These include the detailed progress of profile variations with time, low color-to-light amplitude ratios, the occasional display of retrograde traveling waves, and rotational m-mode splitting. Up to now three tests have been proposed for detecting radial pulsation in β Cepheids: (1.) the progress of radial velocity and line profile variations (width changes being discontinuous if present at all; S79, A77), (2.) the observation of a high color-to-light ratio (SW78a), and (3.) the presence of hydrodynamic effects in profiles at certain phases (SW78b, SM78, CS80). Stamford and Watson demonstrate that the double-lobe structure at broad-line phase can be easily produced by a shock. In contrast, conditions must be optimal even to approximate this feature with NRP theory (S77). Their success in modeling profiles in BW Vul and the obvious presence of a shell in σ Sco (emission lines!; S79) show that discontinuous width changes are easily explained by hydrodynamic effects in a radially pulsating atmosphere. Further, the persistence of such features particularly in UV profiles (see data of L78, S79) implies that this activity is pervasive in many or all β Cepheids. Finally, high color-to-light ratios suggest that 8 out of 10 β Cepheids are radial pulsators (SW78a). Indeed the best case for nonradial pulsation now may be 12 Lac (SW78a, J78). A good test for this mode assignment would be to see how the line widths change in new observations of this star. Continuous line width changes, without evidence of shells, would lend valuable support to the NRP designation. For now I venture that all β Cepheids, including 12 Lac, will turn out to have a detectable, if not dominant, radial mode, which in some stars drives atmospheric shocks and in others excites a nearby nonradial mode.

4. Operational Guidelines for β Cephei Star Designation

A rigorous definition of β Cepheids is still elusive because of the complicated qualifications one has to make. Therefore I consider the following a set of "operational guidelines" for classifying a classical β Cepheid:

"A β Cepheid resides in the upper left portion of the HR Diagram and exhibits continuous changes in light and radial velocity (line centroid!) which are too rapid to ascribe to stellar rotation or binary motion, and which are stably periodic over several years (except for multiperiodic modulations). Its optical spectral lines may exhibit opposite profile asymmetries every half period and possible discontinuous changes in width."

Notice these guidelines contain no reference to a precise position on the HR-D, a period or amplitude range, or a single means of detection. They allow for slowly rotating β Cepheids like γ Peg, that show virtually no profile changes, variables which show changes in line asymmetry but not width (β Cep; G74, S79), as well as those showing discontinuous line width changes (σ Sco (CS80), 12 Lac (A77)). What types of stars does it exclude? They exclude all 53 Per variables (including 10 Lac), which show continuous line width changes and usually unstable periods. However, it now remains to be seen if indeed the USPVs have a high degree of period stability and continuously varying line profiles. A failure of one of these two tests will delineate the low-P boundary of the β Cepheids and allow a more precise definition of the class.

REFERENCES

Allison, A. M., Glaspey, J. W., and Fahlman, G. G. 1977, A. J., 82, 283, (A77).

Campos, A. J., and Smith, M. A. 1980, in preparation, (CS80).

Elst, E. W. 1979, I.A.U. Info. Bull. Var. Stars, No. 1562, (E79).

Goldberg, B. A., Walker, G. A., and Odgers, G. J. 1974, Astron. Astrophys., 32, 355, (G74).

Jakate, S. 1979, A. J., in press, (J79).

Jerzykiewicz, M. 1978, Acta Astr., 28, 465, (J78).

Lesh, J. R. 1978, 4th Trieste Conf.: High Resolution Spectrometry, (ed. M. Hack), p. 344, (L78).

Lomb, N. R. 1978, M.N.R.A.S., 185, 325, (78).

Mel'nikov, O. A., and Popov, V. S. 1975, Pulsating Stars, ed. B. V. Kukarkin, (New York: John Wiley & Sons), p. 238, (MP75).

Petrie, R. M., and Pearce, J. A. 1962, Pub. D.A.O., 12, 1, (PP62).

Shobbrook, R. R. 1979, Proc. Astr. Soc. Aust., 3, in press.

Smith, M. A. 1977, Ap. J., 215, 574, (S77).

__________ 1979, Tucson Conf. on Nonrad. Puls., ed. H. Hill and R. Kippenhahn, in press, (S79).

Smith, M. A., and McCall, M. L. 1978, Ap. J., 221, 861, (SM78).

Stamford, P. A., and Watson, R. D. 1978a, I.A.U. Colloq. No. 46, ed. F. M. Bateson, in press, (SW78a).

__________ 1978b, Proc. Astr. Soc. of Aust., in press, (SW78b).