I.A.U. Symposium No. 59 On Stellar Stability And Evolution

IAU symposium No. 59 on 'Stellar Stability and Evolution' was held at Mount Stromlo between August 16—18, 1973. About 65 participants from a dozen countries attended it.

The Symposium was divided into six sections :(1) Survey of the Problems in Stellar Instability and its Relation to Stellar Evolution (2) Pulsation and the Young Disc Population (3) Large Mass Stars, Secular Stability in Supergiants, Critical Masses (4) Halo and Old Disc Populations (5) Eruptive and Explosive Variables and (6) Instability Mechanisms. Each section had one or two review or introductory talks followed by contributed papers.

Ikco Iben commenced the scientific session by presenting the status of the theoretical understanding of the stellar instability from the point of stellar evolution in a fairly exhaustive though brief way. Some of the main points of his talk were :

(1) Among regular variables of large amplitudes, RR Lyr stars are of low mass and classical cepheids of large mass, with He^+ ionization as the principal driving mechanism; (2) Blue edge of the instability strip is sensitive to mass and helium abundance and the red edge due to the quenching of convection due to He^+ ionization; (3) In stars of low surface temperature, the fundamental mode wins over higher modes, a fact used in finding distances of RR Lyr stars; (4) β Cep stars are near exhaustion of hydrogen in the core; they lie in a band parallel to the main sequence though no exciation mechanism has yet been found; (5) s-processing in thermal instability regions may occur, though the process may not be repetative in low mass stars; (6) Pulsars are rotating neutron stars; X-ray pulsars probably occur in binary stars of short periods; (7) Novae are probably binary systems with one component as white dwarf, the other a red giant; and (8) Supernovae type I are binaries and type II single stars. Icko Iben stressed that (a) a close look should be taken at the conversion of observed quantities to theoretical ones, or vice versa, specially their dependence on the abundance of heavy elements, (b) excitation mechanism for β Cep stars needs to be found (c) whole star models for δ Scuti stars should be constructed, (d) observed drifts due to magnetic field etc. should be examined and (e) mechanism of supernovae explosion should be fully explored.

Eggen felt there was a strong case from the available observational evidence for dividing the cepheids into three populations : (i) young dise population (classical cepheids), (ii) the old disc population (W Vir stars) and (iii) the halo population. This was based on groupings on the (M_{Bol}, log T_{eff}) plane. RV Tauri and δ Scuti stars have also all three population examples. He also mentioned that N and R variables have δ Scuti type variation superimposed on Mira type variation; the cause of this variation is not yet understood.

A. N. Cox reviewed the recent linear and non-linear pulsation calculations. Phase lag of half a period, given by non-linear theory, is given by linear theory also if the boundary conditions are properly taken into account. Growth rates for all modes agree within fifty percent between linear and non-linear theory. Period is the easiest parameter to obtain; it increases a little bit with amplitude. The same result is obtained for the instability of modes between the two treatments. Radius amplitude variation between linear and non-linear theory does not match after quarter of a cycle. Computationally, it is necessary that smooth opacity tables be used, i. e. in place of 500 points as at present, at least 1000 points should be employed. One needs a better treatment of radiation in the surface layers and it is desirable to have time dependent convection in the code. Among current problems in non-linear pulsation calculation, Cox mentioned (a) discussion of transition lines, i. e. boundary between Type I and Type III Christy variations, (b) correlation of light curve humps with stellar mass, (c) pulsation modes for cepheids—it may be that no classical cephied is in harmonic mode, and (d) relation between $\langle \log T_{eff} \rangle$ to equilibrium log T_{eff}—this is essentially the problem of how to plot the points so the comparison with observations is easy.

R. Stobie referring to the mass anomaly for cepheids discussed the estimates for the ratios

$m_Q / m_{evol} \simeq 0.7$, $m_{beat} / m_{evol} \simeq 0.3$,

and $m_\phi / m_{evol} \simeq 0.6$. The last of these ratios depends on the non-linear theory and is highly sensitive to the opacity. The first estimate is relatively more trustworthy.

Parson noted that the temperature of the classica cepheids may be lower by about 150° K.

The presence of a number of non-variable stars in the instability strip of the H.R. diagram may be due to composition differences according to A. Cox, Tabor and King; there appears to be a correlation between non-pulsation and rotation, as well as pulsation and metallicity.

Bessel in a discussion of the parameter and composition of δ Scuti, dwarf cepheids and R R Lyr stars concluded that the difference between Population I and Population II stars is essentially one of mass with $m_{Pop\ I} / m_{Pop\ II} \simeq 10$.

McNamara discussed dwarf cepheids and concluded that a majority of these stars have v sin i $\leqslant$ 20 km/sec, and the metallicity is a function of the period. Stars, with period $\simeq 1\text{-}2^h$ are old disc population, whereas those with period $\simeq 2\text{-}4^h$ are young Population I stars. For short periods, log g= 4.0. log $m/m_\odot$ =0 and for long periods log g = 3.6—3.7, and log $m/m_\odot \simeq 0.5$. Strong line RR Lyr stars may be an extension of δ Scuit stars.

Stobie and Shobbrook discussed the multiple periodicities in δ Sct stars. The basic question is whether these could be explained in terms of linear or non-linear oscillations. The fact that the oscillations over a period of several years can be described by only a few terms in the Fourier expansion indictes that the oscillations are primarily linear..

Shorbbrook reported that in the (β, $[C_1]$) —plane and β CMa stars and some apparent non-variables lie in a small region above the main sequence.

Tayler and Papaloizou discussed the non-linear instability of stars with $m > 100m_\odot$. In the linear theory, the overtones are damped. What about coupling between modes ? For small amplitude, the coupling time is small and the linear theory is satisfactory. But when the amplitude is large, the transfer of energy from fundamental to overtones may be large; then non-linear effects may become large. Coupling between radial and non-radial modes in a rotating massive star is being considered at the moment. It is possible that even in δ Sct stars, the coupling between different modes may be significant.

According to Maeder, all supergiants of class B,A and F are variables and they live above the cepheid strip in the M_V vs log P plot.

Osmer discussed the *uvby* observations of supergiants in SMC and LMC and Buscombe the variations in line intensities in A type supergiants.

In his introductory review of Red Variables and Evolution on the Giant Branches, Feast mentioned recent detection of Mira variables with periods over 200^d in metal rich globular clusters, like 47 Tuc, NGC 6553, NGC 5927; these clusters have no RR Lyr star. Magellanic cloud clusters contain some very red stars with B—V $\sim$ 2.4. Some of them may be carbon stars. Some of them are variables, others are not. Kron 3 has a star at B—V=2.4 which is a carbon star; NGC 419 and NGC 121 have also at least one carbon star each. There are no carbon stars known in our galaxy, which are so red though we have fairly red CH stars in our galaxy. It is possible that these clusters are younger than the galactic globular clusters.

Wood discussed the evolution of asymptotic giant branch stars and pointed out that if the luminosity exceeds a certain limit, the star of mass $0.9\,m_\odot$ becomes unstable. Mira variables can be associated with first overtone and not fundamental mode. This shows the possibility of mass loss. High luminosity models show the possibility of shell formation, leading to the formation of planetary nebulae.

Based on his studies of the periods of RR Lyr in the SMC and LMC, Graham showed that the absolute mean magnitude of these stars is same in these clouds, i.e. $0^m.5$ to within $0^m.05$.

Giving the introductory talk for the session on short period variables, horizontal and asymptotic branch and planetary nuclei, P. Demarque mentioned that horizontal branch stars occur where RR Lyr stars are. Period changes, including some rapid ones, have been observed in these stars. These stars have He burning core with H-shell burning. Semi-convection plays an important role in these stars, though its treatment is not satisfactory. Semi-convection can increase the lifetime by a factor of two. When helium abundance in the core gets very small, an overshooting takes place with injection of helium in the core from the outer layers; this causes instability. This composition instability track passes through the instability strip.

Cepheid variables in Population II clusters show a clumping of period around 1 day and around 8 days; there may be a clumping at a somewhat higher period also but the present data are not enough to draw a satisfactory conclusion.

Graham mentioned the mean properties of RR Lyr variables in the Magellanic clouds.

Schatzman in his introduction to Eruptive and Explosive Variables classfied them into Novae, U Gem stars, Flare stars and T Tauri stars, on the basis of the ratio of total energy emitted in explosion to that between explosions. It is only a surface phenomenon so far as flare stars are concerned, though the entire star may be taking part in the case of Novae and U Gem stars. In flare stars, the point of intersection of $V_{11}=0$ and $H_{11}=0$ are supposed to be points where the flares originate, like in the sun. Novae type I are binaries with the exploding component as a white dwarf and the other one a Be star, while novae type II are single stars. The explosion mechanism is not yet well understood. Non-symmetric ejection of mass may be helped by rotation.

Warner discussed small oscillation, with periods between 1/2 min to $1\frac{1}{2}$ min in the light curves of dwarf novae. These can be explained by assuming a ring around the white dwarf component and formation of hot spots thereon due to accretion of matter from the other component.

Paul Ledoux reviewed briefly the non-radial pulsation of purely spherical stars. The 300 sec solar oscillation is related to non-radial oscillation. The linearized adiabatic equations are of fourth order in r; the solutions are degenerate and magnetic field, tidal effect, etc. do not fully remove the degeneracy. The coupling between various modes can be important. No gravity mode has been found which are vibrationally stable.

According to R. J. Tayler, if there is a linked poloidal and toroidal flux, it is not certain that one will get an instability.

Kemp discussed the magnetic field in X-ray binary systems. The magnetic fields correspond to 1-15 k gauss, though the assignment of actual value of the magnetic field is somwhat complicated, a fact not realized earlier.

Zahn discussed the variability in presence of rotation and Smeyers tried to explain the beat phenomena in β CMa stars by including tidal effect in a synchronous rotating star system.

A summary by Icko Iben concluded the symposium.

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