LIFETIME OF DENSITY WAVES AND CLASSIFICATION OF SPIRALS

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Checking the density-wave theory against observations of our own Galaxy has proven very difficult, as witnessed also at this Symposium. Less ambiguous results, however, are obtained for other galaxies. These results involve a) calculating convincing models for a sample of 25 fairly well observed spirals (Roberts et al. 1975) and b) locating the compression zones on the inner edges of the spiral arms.

We have studied the physical parameters of the density wave in more detail. Using Brandt-Belton mass models, and assuming the sound velocity $a = 10$ km s^{-1} and the stability parameter $Q = 1$, we calculated the propagation velocity v_g, the wave energy density E, and the energy loss per shock (assumed isothermal), and from these quantities the kinematic life-time τ and the dynamic life-time T of the density wave. We found $\tau \sim 3.5$ times the rotation period at corotation, therefore continuous or iterating excitation of the density wave is necessary. The galactic shock reduces this time-scale drastically by a further factor of 3. Therefore, a density wave cannot penetrate from one Lindblad resonance to the other, to be amplified, without continuous energy supply. The spiral type T_{sp} of the galaxy (after de Vaucouleurs) is related to the energy density of the spiral wave which in turn depends on the underlying mass distribution:

$$T_{sp} = 6.86 - 3.6 \log E_9$$
$$\pm 0.19 \pm 0.27$$

(correlation coefficient -0.94; rms scatter ± 0.65, mostly due to errors of T_{sp} and E_9 denoting the power 10^9 erg cm^{-2}).

The heavy element abundance (resulting from previous formation of massive stars) is also related to the total energy density of the density wave which continuously triggers stars formation. This is true for the whole sample of galaxies and within individual galaxies. The energy loss agrees well with the measured compression strength (van der Kruit 1973).

REFERENCES

Roberts, W. W., Roberts, M.S., and Shu, F.H.:1975, Astrophys.J. 196,391.
van der Kruit, P. C.: 1973, Astrn. Astrophys. 29, 263.

W. B. Burton (ed.), The Large-Scale Characteristics of the Galaxy, 155–156.

DISCUSSION

Greyber: With your theoretical considerations added to the density wave theory of spiral structure, can one explain Baade's observed dust spiral arms in M31 seen extending inward to much less than 1 kpc from the tiny M31 galactic nucleus, i.e., in a region presumably far inside the Inner Lindblad Resonance? Also, can one explain Arp's observations of the M31 spiral arms extending outward beyond 30 kpc, i.e., presumably far outside the Outer Lindblad Resonance?

Schmidt-Kaler: The mechanism described can work beyond the Lindblad Resonances. The steep onset of the dust arms in the nuclear region is just what is expected as a result of the further development of the Riemann instability.