INSTABILITIES OF HOT STELLAR DISCS

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We use computer simulations to determine the dominant unstable modes of stellar discs having the surface density distribution of Toomre's (1963) model 1 and large random motions in the plane. Particles in the models have their initial coordinates chosen from distribution functions to ensure that the configurations would, in the limit of infinitely many particles, be stationary solutions of the Vlasov and Poisson equations. The 40,000 particles in our simulations are constrained to move on a plane and we use a polar grid based Fourier method to determine the force field (Sellwood 1982). The surface density is smoothly tapered to zero at six scale lengths and the softening length is 1/30th of the outer radius of the disc.

Kalnajs (1976) has given a family of distribution functions for this disc which have a nearly constant Q at all radii when Q is near to 1, but hotter members of the family have Qs which rise steadily outwards as shown in Figure 1(a). The dominant modes of these discs were extracted from simulations by a least squares fit to the logarithmic spiral Fourier coefficients of the particle distribution. As expected, the growth rates decrease substantially as pressure support is increased, but we still find growth rates as great as one tenth the pattern speed when the mass weighted average Q is as high as 2.04. (Pure pressure support corresponds to a mean Q of 2.77). Composite models which contain two populations, one having a large degree of pressure support, the other little random motion, tend to be even more unstable for their mean Q than a single population disc.

New distribution functions, which are generalisations of those given by Kalnajs, enable us to study models where Q behaves differently with radius (dashed curves, Figure 1(a)). These two models have a very similar mean Q, but the growth rate of the model having the higher central Q is one fifth that of the other.

All these results are plotted in Figure 1(b) which illustrates that mean Q does not correlate well with growth rate. A somewhat better correlation is found with the central value of Q (not shown here) but

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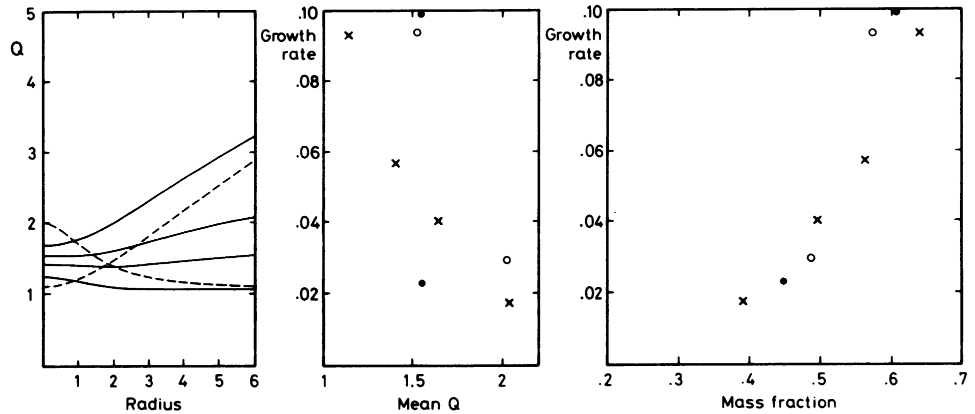

Figure 1. (a) The radial variation of Q for four Kalnajs functions (full curves) and two new functions (dashed curves). (b) Growth rates plotted against mean Q for Kalnajs functions (crosses), composite models (open circles) and new functions (filled circles). (c) The same growth rates plotted against fraction of mass on nearly circular orbits.

the tightest correlation we have found is shown in Figure 1(c). The absiccae are the fraction of mass in the models on "nearly circular" orbits, defined by the condition:

$$(a-p)/(a+p) < 0.5$$

where a and p are the apo- and peri-galactica of the unperturbed orbit of the star.

Three conclusions can be drawn from our results to date: (a) a large amount of random motion substantially reduces the growth rate of instabilities, (b) high Q near the centre is much more effective at reducing growth rates than increased random motion further out, and (c) the growth rate correlates with the fraction of mass on nearly circular orbits. It remains to be seen whether these conclusions can be generalised to models having different distributions of mass.

References

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