Dust and gas in triaxial galaxies

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There are many reasons to consider the dynamics of triaxial galaxies. Elliptical galaxies are not rotationally flattened (Illingworth, this conference) and their isophotal profiles are often twisted. N-body simulations of collapse have produced a number of final state figures which are triaxial. Even those still skeptical will have to grant that barred spirals (a category which seems to include the Galaxy) are certainly not axisymmetric.

These arguments do not demonstrate convincingly that ellipticals are triaxial. Illingworth (this conference) has shown that low luminosity ellipticals appear to be consistent with oblate, rotationally flattened models and has argued that the continuity in all properties of faint and bright ellipticals suggests that all ellipticals are oblate. Clearly, one needs a clean, decisive probe. Gas and dust provide just that. Details of the work discussed here may be found in a paper submitted to the Astrophysical Journal.

We have analyzed two model Hamiltonians designed to approximate the inner and outer regions of a triaxial galaxy. These enable us to: (1) find isolating integrals of motion, (2) integrate the equations of motion in one subclass, (3) find the periodic orbits and assess their stability using reduced potentials or Liapunov functions, (4) associate families of orbits (box, tube, shell, etc.) with perturbations of the stable periodic orbits, and (5) apply Melnikov's method to deduce the fate of dissipating gas (or the effect of dynamical friction on the distribution of globular clusters) in these potentials (stable periodic orbits "attract," whilst unstable ones "repel").

One important feature is the structural instability of axisymmetric systems. In these potentials there is only one orbit family: all orbits circulate about the axis of symmetry tracing out a "tube." The only exceptions are the neutrally stable radial orbits lying in the plane and the unstable orbits which go over the pole. At the slightest introduction of nonaxisymmetry, new orbit families emerge. A class of radial orbits becomes stable to perturbation (parenting box orbits), as does one of

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the polar orbits (yielding a family of tubes in a different orientation).

With these results, the unusual configurations of dust and gas seen in many ellipticals become compelling evidence for triaxiality. Particular examples are NGC 2768, NG3 5363, Cen A and especially NGC 2685, the Spindle galaxy which has two loops of gas. Recently, there have been proposals to explain polar rings as "quasi-stable" orbits in oblate configurations. "Quasi-stability" is a way of proposing to find gas in an unstable orbit which should actually behave as a "repellor." There are clear signs that such orbits are not responsible for these configurations. Figure 1 shows the difference in appearance of dust and gas started in

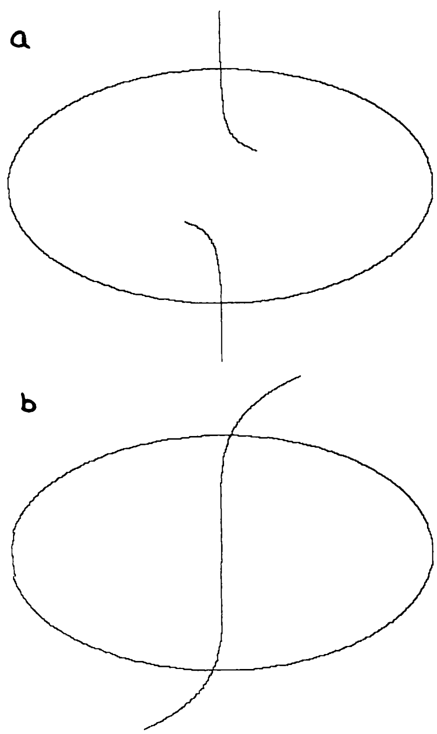

Figure 1: Appearance of a dust lane (open curve) relative to the stellar figure (ellipse) formed by a) capture in the unstable polar orbit of an oblate figure, b) capture in the stable periodic orbit of a triaxial figure.

an unstable polar configuration and allowed to evolve (1a) and that being attracted to a stable periodic orbit (1b). Cen A is a good example of the latter. We challenge advocates of the former to find something which looks like Figure 1a. A greater challenge is presented by NGC 4125 (Bertola, this conference). In this galaxy the stellar rotation is maximized at an angle of 30° with respect to the major axis, a position coincident with the dust lane. This is impossible to reconcile with an axisymmetric model and provides compelling evidence that this is indeed a strongly triaxial galaxy.

The combined study of gas and stars in elliptical galaxies provides a powerful probe of their three dimensional shapes and dynamics. Observations of elliptical galaxies with skewed dust lanes are of particular interest in this context.