

Contents

1	Introduction	5
2	Description of the Orbital Motions	12
2.1	Stellar Orbits in a Spherical Galaxy	12
2.2	Frequencies in a Spherical System	18
2.3	Combining Orbits to make a Model	21
2.4	Hamiltonian Description of Orbital Motion	24
2.5	Expansions in terms of the angle variables	27
2.6	Motion in a Spherical Potential Revisited	28
2.7	Simple pendulum	33
2.8	Axisymmetric systems - Stäckel systems	36
2.9	Action & Angle Description for Stäckel Systems	42
3	General Perturbation Theory	46
3.1	Spherical Perturbations of Spherical Systems	46
3.2	Coplanar Bar-like Perturbations	50
3.3	More General Single Resonant Perturbations	56
3.4	Double Resonance Perturbation - the Overlap Criterion	58
3.5	General Perturbations - KAM Theory	60
3.6	Slowly Tumbling Perturbations	62
3.7	Summary	67
4	Constructing Equilibrium Models	68
4.1	Evolution Equation for Stellar Systems	68
4.2	Jeans' Theorem	71
4.3	Velocity Moments	72
4.4	Spherical Systems	73
4.5	Rotating Spherical Systems	78
4.6	Axisymmetric Systems	79
4.7	Single Resonance Systems	81
4.8	Other Models	82
5	Non-Rotating Spherical Systems	83
5.1	Formulation of the Matrix Eigenvalue Problem	83
5.1.1	The Response Density	84
5.1.2	The Matrix Eigenvalue Equation	89

5.2	Properties of the Poisson Operator	92
5.3	Purely Growing Modes	93
5.4	Causality, Overstable Modes & Landau Damping	95
6	Isotropic Systems	102
6.1	Proof of No Overstability	102
6.2	Stability to Perturbation	105
6.3	Summary	109
7	Anisotropic Spherical Systems	110
7.1	Radial Perturbations	111
7.2	Purely Growing Modes	111
7.3	Radial Orbit Instability	115
	7.3.1 Physical Explanation of Instability	120
	7.3.2 Implications for Galactic Centres	121
7.4	Effects due to a Central Compact Mass	123
7.5	Balance between Resonances	135
7.6	Summary	143
8	Spherical Systems with Rotation	145
8.1	Formulation of the Matrix Eigenvalue Problem	145
8.2	Radial Orbit Instability	150
8.3	Tumbling Instability	153
8.4	Rederivation from Orbital Perturbation Theory	155
8.5	Destabilisation due to Energy Loss	157
8.6	Resonant Destabilisation of the Tumbling Mode	160
8.7	Merging of Radial Orbit and Tumbling Instabilities	161
8.8	Summary	163
9	Axisymmetric Systems	164
9.1	Matrix Equation for General Integrable Systems	164
9.2	Matrix Equation for Axisymmetric Stäckel Systems	167
9.3	Purely Growing Instabilities	169
9.4	Stäckel Perturbations to Stäckel Potentials	173
9.5	Instability in Non-Integrable Systems	176
9.6	Tumbling Instability	178
9.7	Summary	180

10 Numerical Modelling Techniques	181
10.1 Overview of Numerical Techniques	182
10.2 Smooth Potential Method	185
10.3 Limitations of the Numerical Simulations	190
10.4 Reproduction of Linear Perturbation Results	199
11 Non-Linear Evolution and Endstates	209
11.1 Radial Orbit Instability	210
11.1.1 A Non-Linear Model - Exchange of Stability	222
11.1.2 Triaxial Endpoints	231
11.2 Tumbling Instability	233
11.3 Relevant Observations of Real Galaxies	247
12 Disc Galaxies	252
12.1 Epicycle Orbits	252
12.2 Matrix Equation and WKB Approximation	256
12.2.1 The WKB Approximation to the Solution of Poisson's Equation	262
12.3 Jeans' Instability	267
12.4 Propagation of WKB Wave Packets	272
12.5 Lopsided Instabilities	278
12.6 Two Stream Instability	282
12.7 Global Bar Modes - the Lindblad Conjecture	284
12.8 Edge & Groove Modes	296
12.9 Firehose Instability	299
12.9.1 Shift Mode	301
12.9.2 Variational Principle	302
12.10 Summary	309
A Setting up N Body Datasets	310
A.1 Generalised Polytropes with a Central Point Mass	313
B Spherical Harmonic Addition Theorem	314
C Expansion of Spherical Harmonics in Orbital Parameters	316
C.1 Orthogonality Relations	317

D	The Poisson Operator for Axisymmetric Discs	319
D.1	The Poisson Operator for General Non-Axisymmetric Perturbations	321
	References	328
	Index	346

