

Contents

1	Introduction	13
2	Plasma turbulence	19
2.1	Principles of turbulence	19
2.1.1	Basic equations	19
2.1.2	Conservation laws	22
2.1.3	Cascades	24
2.2	Plasma micro-instabilities	27
2.2.1	Interchange instability	28
2.2.2	Drift-wave instability	30
2.3	Drift waves	31
2.3.1	Dispersion relation of stable drift waves	32
2.3.2	Influence of finite ion mass	34
2.3.3	Unstable drift waves	34
2.3.4	Influence of electron collisions	35
2.4	Plasma turbulence models	36
2.4.1	Hasegawa-Wakatani model	37
2.4.2	Curvature effects	41
3	Zonal flows	43
3.1	Zonal potential modes in plasmas	43
3.1.1	Zonal flows	44
3.1.2	Geodesic acoustic mode	45
3.2	Turbulent Reynolds stress drive	48
3.3	Drift-wave zonal-flow dynamics	52
3.3.1	Model equations	52
3.3.2	Self-consistent states	54
3.3.3	Drift-wave self-regulation	57
3.4	Damping mechanisms	58
3.4.1	Collisional damping	59
3.4.2	Geodesic transfer effect	60



Contents

4 Data analysis	63
4.1 Basic principles of statistical analysis	63
4.2 Correlation analysis	67
4.3 Spectral analysis	68
4.3.1 Fourier transformation	68
4.3.2 Wavelet transformation	69
4.4 Bispectral analysis	70
4.5 Analysis of the energy transfer	71
4.5.1 Ritz method	73
4.5.2 Kim method	74
4.6 Conditional averaging	76
5 Experiment and diagnostics	79
5.1 The Stellarator TJ-K	79
5.1.1 Experimental setup	80
5.1.2 Magnetic field structure	82
5.2 Diagnostics	86
5.2.1 Langmuir probes	86
5.2.2 2D-movable probe unit	88
5.2.3 Poloidal Reynolds stress array	90
6 Background profiles and turbulence	93
6.1 Background parameter	93
6.1.1 Equilibrium profiles	93
6.1.2 Equilibrium trends with experimental control parameters	99
6.2 Dimensionless parameters	101
6.2.1 Mass ratio μ^*	101
6.2.2 Plasma beta β	102
6.2.3 Drift scale ρ_s	103
6.2.4 Collisionality C	104
6.2.5 Parameter dependency	105
6.3 Turbulence	106
6.3.1 Fluctuation level	106
6.3.2 Spectra	110
6.4 Summary of the chapter	113
7 Zonal flows	115
7.1 Characteristics of the zonal potential	115

7.2	Structure and dynamics	120
7.2.1	Dynamics in the poloidal cross section	120
7.2.2	Dynamics on a flux surface	122
7.3	Spectral analysis	126
7.3.1	Frequency distribution	126
7.3.2	Collisionality scaling of spectral power	127
7.4	Summary of the chapter	130
8	Reynolds stress drive	133
8.1	Background Reynolds stress	133
8.1.1	Geometry dependence	134
8.1.2	Coherence of velocity components	141
8.2	Reynolds stress dynamics	145
8.2.1	Higher order moments	145
8.2.2	Zonal flow drive	148
8.2.3	Cross-field coupling	154
8.3	Summary of the chapter	156
9	Energy transfer in the drift-wave zonal-flow system	159
9.1	Nonlinear coupling with zonal flow	159
9.1.1	Bicoherence during zonal flow occurrence	160
9.1.2	Collisional scaling of coupling strength	163
9.2	Analysis of energy transfer channels	164
9.2.1	Energy transfer with the zonal flow	165
9.2.2	Influence of collisionality	169
9.3	Summary of the chapter	171
10	Summary and conclusion	173
Bibliography		177