

Contents

1	General Introduction	1
1.1	Solar Structure and Mean Flow	1
1.1.1	Solar Structure	1
1.1.2	Observation of Solar Mean Flow, Differential Rotation and Meridional Flow	3
1.2	Theory and Numerical Calculation for Differential Rotation and Meridional Flow	5
1.2.1	Gyroscopic Pumping and Thermal Wind Balance	5
1.2.2	Numerical Calculations for Differential Rotation and Meridional Flow	8
1.3	Remaining Problems	12
1.4	Reduced Speed of Sound Technique	13
1.5	Thesis Goals	14
	References	15
2	Basic Equations and Development of Numerical Code	19
2.1	Model Setting	19
2.1.1	Equations	19
2.1.2	Background Stratification and Radiation	20
2.1.3	Setting for RSST	21
2.1.4	Divergence Free Condition for Magnetic Field	22
2.1.5	Equation of State	23
2.2	Numerical Method	24
2.2.1	Space Derivative and Time Integration	24
2.2.2	Artificial Viscosity	25
2.2.3	Peano-Hilbert Space Filling Curve for MPI Communication	26
2.2.4	Yin-Yang Grid	28
2.2.5	Big Data Management	28
2.2.6	Code Performance	30
	References	30

3	Structure of Convection and Magnetic Field Without Rotation. . . .	33
3.1	Introduction.	33
3.2	Model.	34
3.3	Results	35
3.3.1	Structure of Convection and Magnetic Field	35
3.3.2	Integrated Energy Flux	40
3.3.3	Analysis Using Spherical Harmonics for Hydrodynamic Cases.	42
3.3.4	Analysis Using Spherical Harmonics and Probability Density Function for Magnetohydrodynamic Cases	44
3.3.5	Generation and Transportation of Magnetic Field.	48
3.4	Discussion and Summary	55
	References	57
4	Reproduction of Near Surface Shear Layer with Rotation	59
4.1	Introduction.	59
4.2	Model.	61
4.3	Results	61
4.4	Calculation with High Rotation Rate and Solar Luminosity	70
4.5	Summary and Discussion	71
	References	73
5	Concluding Remarks	75
5.1	Summary of Thesis	75
5.1.1	Achievements	75
5.1.2	Findings	76
5.2	Remaining Problems and Future Work	76
5.2.1	Comparison with Helioseismology	76
5.2.2	Proper Reproduction of Solar Differential Rotation	77
	References	77
	Appendix	79
	Curriculum Vitae	81

Thermal Convection, Magnetic Field, and Differential
Rotation in Solar-type Stars

Hotta, H.

2015, XII, 81 p. 49 illus., 11 illus. in color., Hardcover

ISBN: 978-4-431-55398-4