课程详述

COURSE SPECIFICATION

以下课程信息可能根据实际授课需要或在课程检讨之后产生变动。如对课程有任何疑问，请联系授课教师。

The course information as follows may be subject to change, either during the session because of unforeseen circumstances, or following review of the course at the end of the session. Queries about the course should be directed to the course instructor.

1.	**课程名称 Course Title**	计算空间物理学基础 Computational Space Physics
2.	**授课院系** **Originating Department**	地球与空间科学系 Department of Earth and Space Sciences
3.	**课程编号** **Course Code**	ESS411
4.	**课程学分 Credit Value**	2
5.	**课程类别** **Course Type**	专业选修课 Major Elective Courses
6.	**授课学期** **Semester**	春季 Spring
7.	**授课语言** **Teaching Language**	中英双语 English & Chinese
8.	**授课教师、所属学系、联系方式（如属团队授课，请列明其他授课教师）** **Instructor(s), Affiliation& Contact** **（For team teaching, please list all instructors）**	张彬铮，香港大学 邮箱：binzheng@ucar.edu Binzheng Zhang, The University of Hong Kong E-mail: binzheng@ucar.edu
9.	**实验员/助教、所属学系、联系方式** **Tutor/TA(s), Contact**	待公布 To be announced
10.	**选课人数限额(可不填)** **Maximum Enrolment（Optional）**	

		讲授 Lectures	习题/辅导/讨论 Tutorials	实验/实习 Lab/Practical	其它(请具体注明) Other（Please specify）	总学时 Total
11.	授课方式 Delivery Method					
	学时数 Credit Hours	20		12		32

12.	先修课程、其它学习要求 Pre-requisites or Other Academic Requirements	CS102B 计算机程序设计基础 B CS102B Introduction to Programming B
13.	后续课程、其它学习规划 Courses for which this course is a pre-requisite	
14.	其它要求修读本课程的学系 Cross-listing Dept.	

教学大纲及教学日历 SYLLABUS

15. 教学目标 **Course Objectives**

本课程系统介绍空间物理数值计算方法的基础理论和数值实现，重点介绍磁流体，粒子和混合模拟三种方法的物理和数值基础，以及计算机建模的过程。通过本课程学习，学生通过学习基础算法，了解各种计算方法应实际科研问题中的应用，具备解决空间物理基础科学问题的基本能力。

This course introduces fundamentals of physical consideration and numerical implementations for computational space physics, with focuses on numerical magnetohydrodynamics schemes, particle-in-cell and hybrid algorithms for space plasma. Through the course study, students will be able to apply fundamentals of computational space plasma physics to solve research problems.

16. 预达学习成果 **Learning Outcomes**

学生完成本课程后，将会掌握以下知识：

1. 一维磁流体力学数值格式；
2. 高维磁流体力学数值格式；
3. 一维粒子模拟程序的建立；
4. 二维粒子模拟程序的建立；
5. 混合模拟算法的设计；
6. 在实际空间物理问题中的应用。

Upon completing the course, students will master the following knowledge:

1. One-dimensional schemes for numerical magnetohydrodynamics;
2. Two/Three-dimensional methods for numerical magnetohydrodynamics;
3. One-dimensional particle-in-cell schemes;
4. Two-dimensional particle-in-cell schemes;
5. Hybrid methods;
6. Applications of various computational methods for space plasma.

17. 课程内容及教学日历 （如授课语言以英文为主，则课程内容介绍可以用英文；如团队教学或模块教学，教学日历须注明主讲人）
Course Contents (in Parts/Chapters/Sections/Weeks. Please notify name of instructor for course section(s), if this is a team teaching or module course.)

第一章 一维线性差分算法（4学时）

一维对流-扩散模拟算法及其稳定性分析；高阶差分格式，激波和通量修正格式

第二章 一维磁流体算法（6学时）

有限体积格式的基本原理，TVD算法的基本原理，磁流体力学方程组的的数值特性

第三章 二维磁流体算法（6学时）

二维有限体积算法的实现，交错网格

第四章 一维动理论算法（6学时）

一维静电弗拉索夫方程的求解，双流不稳定性

第五章 一维粒子模拟算法（6学时）

一维静电粒子模拟，数值稳定性分析，色散分析

第六章 混合模拟算法简介 （4学时）

一维静电混合模拟实现，快速傅立叶变换算法应用

Chapter 1: One dimensional finite differencing schemes（4 Hours）

1D Advection-diffusion fluid code and stability analysis code: higher order finite differencing schemes, shocks, flux-corrected transport;

Chapter 2: One dimensional schemes for magnetohydrodynamics （6 Hours）

1D finite volume method for magnetohydrodynamics, total variation diminishing methods, mathematical properties of the equations of magnetohydrodynamics;

Chapter 3: Two dimensional schemes for magnetohydrodynamics （6 Hours）

2D finite volume method for magnetohydrodynamics, constrained transport (Yee Grid);

Chapter 4: One dimensional kinetic simulations（6 Hours）

1D Vlasov electrostatic code: simple muliti-dimensional programming, two-stream instability, bump-in-tail instability;

Chapter 5: One dimensional particle simulations（6 Hours）

1D1V, time-dependent, electrostatic particle-in-cell code and electrostatic dispersion code: effects of particle number on noise level and in approximating a numerical Maxwellian velocity distribution;

Chapter 6: Introduction to hybrid simulations（4 Hours）

One-dimensional, time-dependent hybrid code; using FFT to evaluate wave dispersion properties, distinguish RH and LH circular polarized waves in simulation data, simulate and diagnose ion cyclotron waves and ion cyclotron instability.

18. 教材及其它参考资料 Textbook and Supplementary Readings

1. *Finite Difference Methods for Ordinary and Partial Differential Equations* by R. L.. LeVeque. – basic methods for hyperbolic, parabolic, and elliptic equations;
2. *Numerical Computation of Internal and External Flows* by C.Hirsch – no plasma physics but a good reference for fluid problems in general;
3. *Plasma Physics via Computer Simulation* by C. K. Birdsall and A. B. Langdon, McGraw-Hill, 1985, 1991 (comprehensive text on the theory, approximations and applications of particle-in-cell codes).

课程评估 ASSESSMENT

19.

评估形式 Type of Assessment	评估时间 Time	占考试总成绩百分比 % of final score	违纪处罚 Penalty	备注 Notes
出勤 Attendance				
课堂表现 Class Performance				
小测验 Quiz				
课程项目 Projects				
平时作业 Assignments		40		
期中考试 Mid-Term Test		20		
期末考试 Final Exam		40		
期末报告 Final Presentation				
其它（可根据需要改写以上评估方式） Others (The above may be modified as necessary)				

20. **记分方式 GRADING SYSTEM**

√A. 十三级等级制 **Letter Grading**
☐ B. 二级记分制（通过/不通过） **Pass/Fail Grading**

课程审批 REVIEW AND APPROVAL

21. **本课程设置已经过以下责任人/委员会审议通过**
This Course has been approved by the following person or committee of authority

地球与空间科学系本科教学指导委员会
Undergraduate Teaching Steering Committee of the Department of Earth and Space Sciences