Introduction

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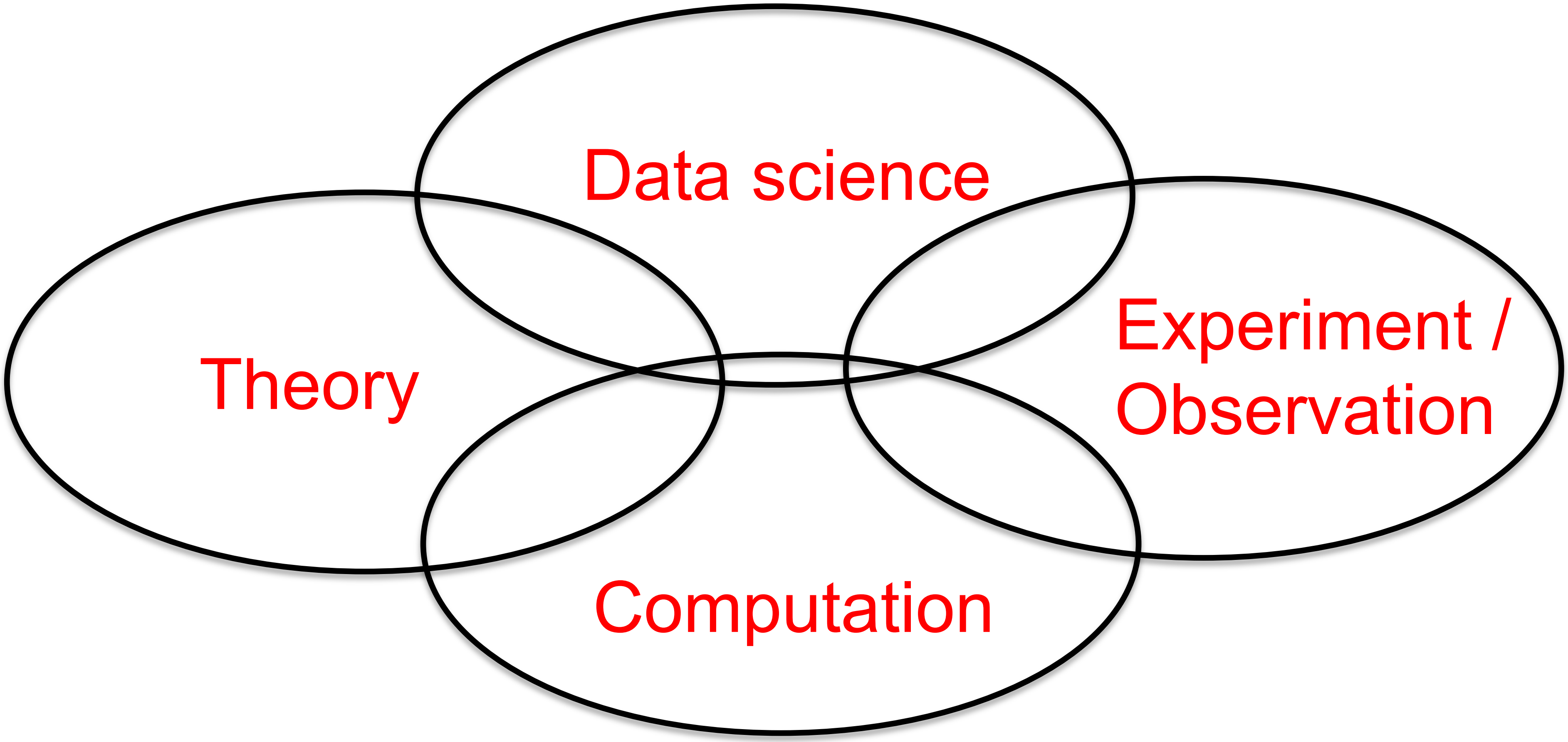
Pillars of scientific inquiry



Astronomical context

Astronomy plays a pioneering role in the big data era.

How to efficiently process and reliably extract information from huge data volume?

Astrophysical context

Theoretical astrophysics has been increasingly relying on numerical calculations and large computer simulations.

How to design accurate, efficient and stable algorithms to solve complex equations?

Link to statistics

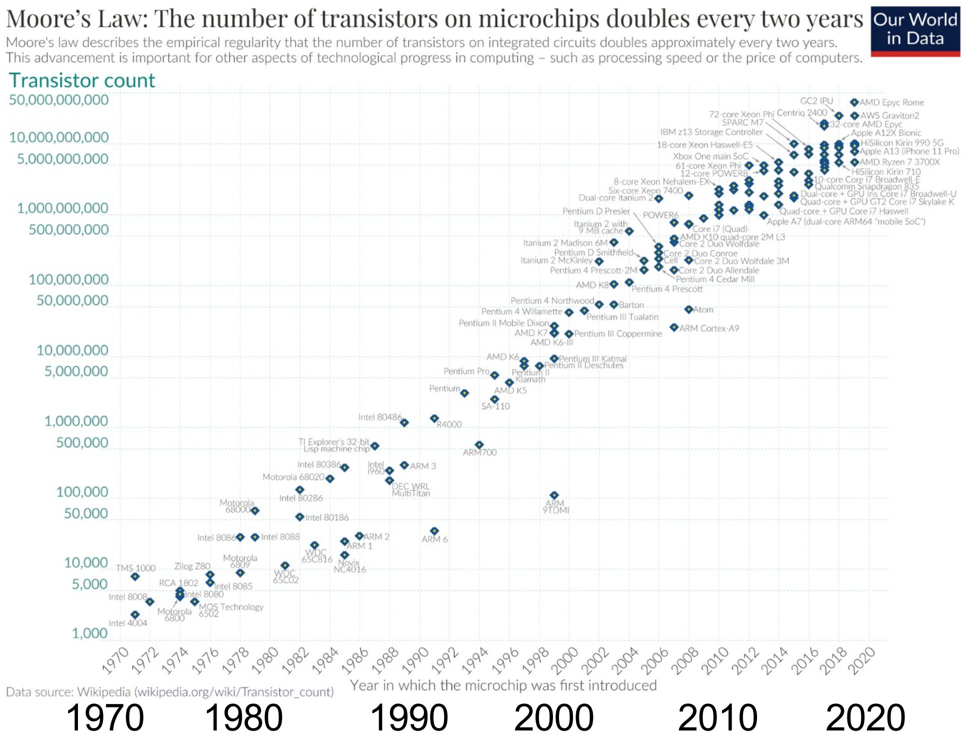
Modern statistics is vast in scope and methodology, and is intimately linked to data science and machine learning.

Astrostatistics

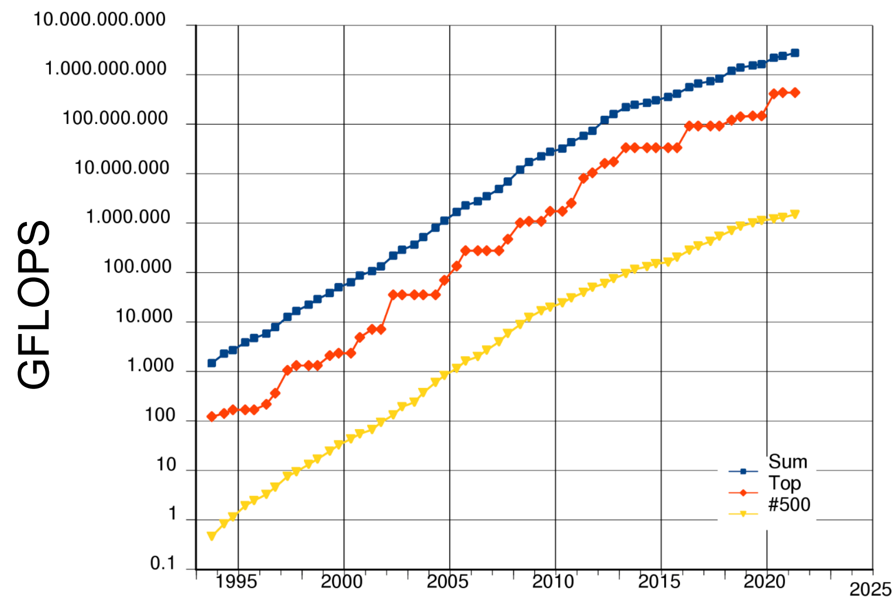
We need to take the advantage of such modern developments to serve our interests.

Link to computational science

The computing power explodes roughly according to Moore's law.

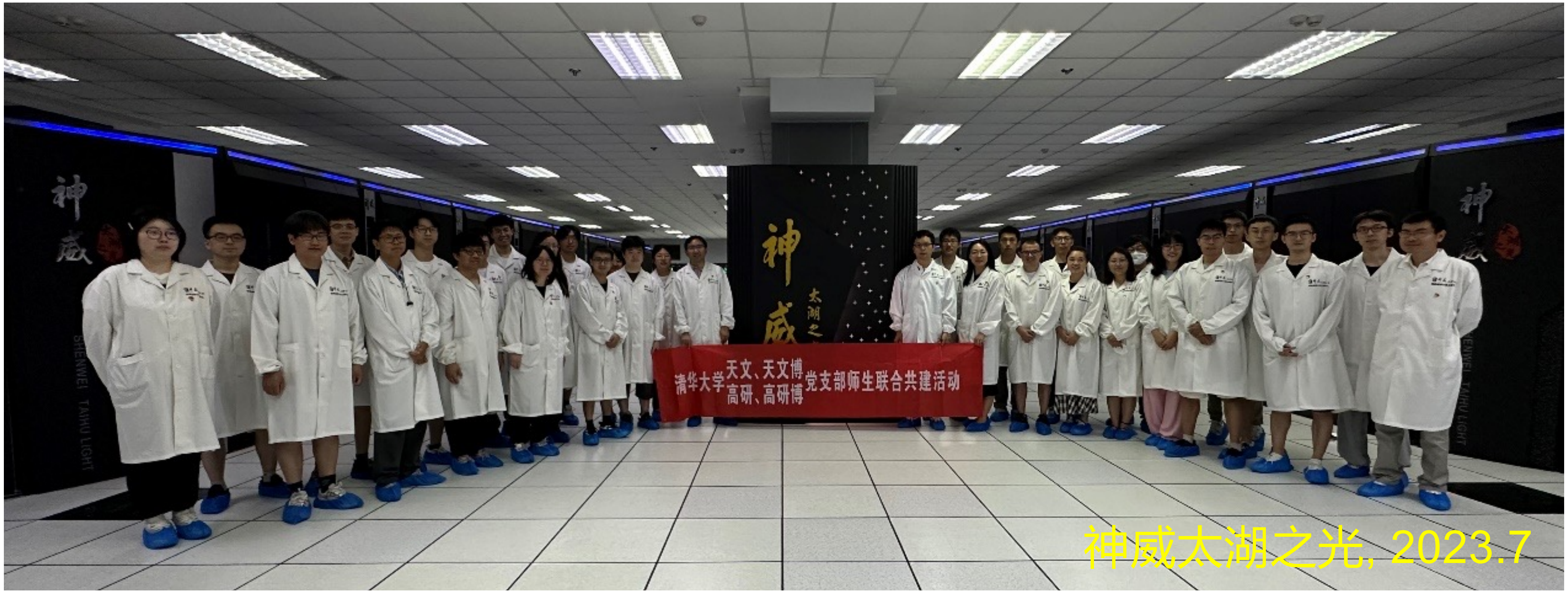


Performance of TOP500 supercomputers



How to best exploit the advances in modern computing architectures?

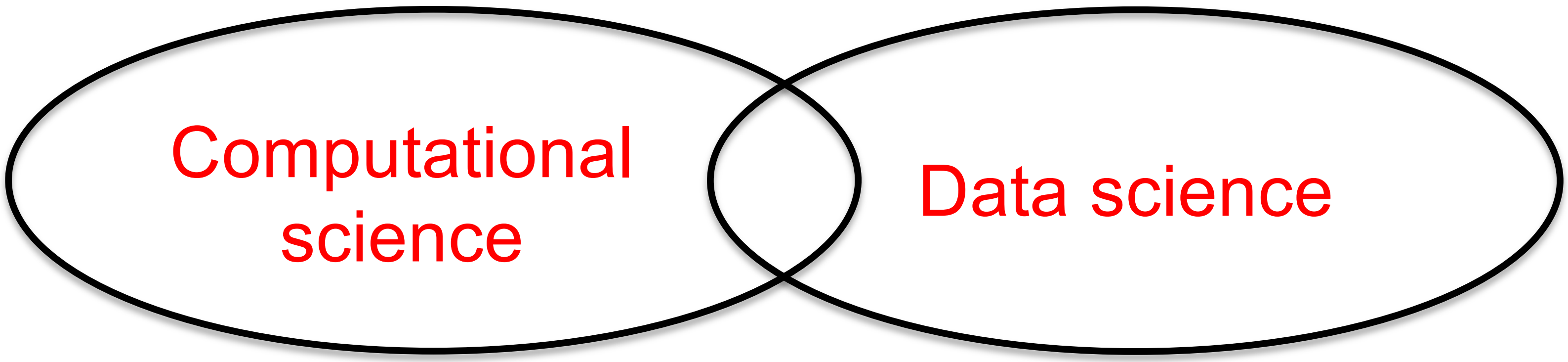
Supercomputing in China



National supercomputing centers in Tianjin, Guangzhou, Wuxi, Chengdu, Ji’nan, Changsha, Zhengzhou, Kunshan, etc.

No longer join the Top500 list. Fastest machines use domestically produced CPUs, and would have ranked the top. (Need users!)

Scope



Main components:

- Algorithm: methods for (efficiently) solving equations and/or analyzing data.

  We focus on algorithms, emphasizing the basic ideas behind, but less on math details.

- Software: computer implementation of the algorithms.

  We only briefly discuss implementation. You will implement some algorithms, as well as using matured software.

Course objectives

- This course provides an overview to statistics and computational methods primarily for astronomers/astrophysicists.
- We hope to get you familiarize with the fundamental tools and methods, mostly numerical, in preparation for your future research in astronomy.
- We place more emphasis on basic principles and ideas (with less mathematical rigor), and real-world applications (mostly drawn from astronomy).

By the end of the course, you should be able to identify appropriate algorithms and software, and potentially design your own customized algorithms, for problems of interest in your research.

Instructors

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Prerequisites

- Calculus, linear algebra, probability theory
- Experience with at least one programming language

The problem sets generally require certain (from minimum to substantial) level of programming. While most problems can be worked out using scripted language such as Python or Matlab, and generally you do need them to make plots, we note that these languages are not designed for scientific computing (and can be exceedingly slow). It is encouraged that you work with a compiled language (C, C++, Fortran) for some problems to gain some proficiency.

Overall, this course is aimed at beginning graduate students or advanced undergraduate students, primarily targeting astronomy students.

Logistics

We will use the university web learning platform （网络学堂）：

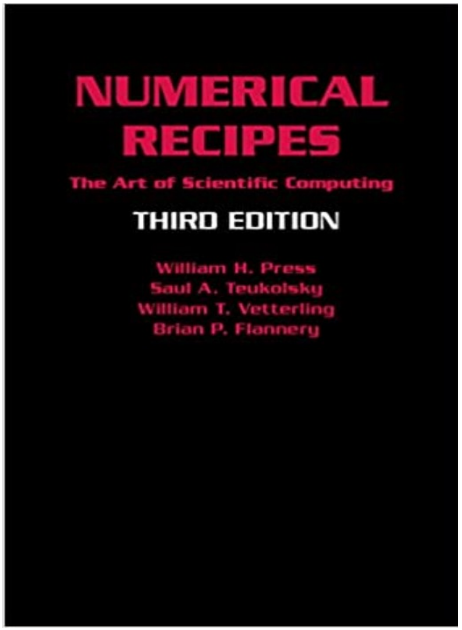
https://learn.tsinghua.edu.cn/

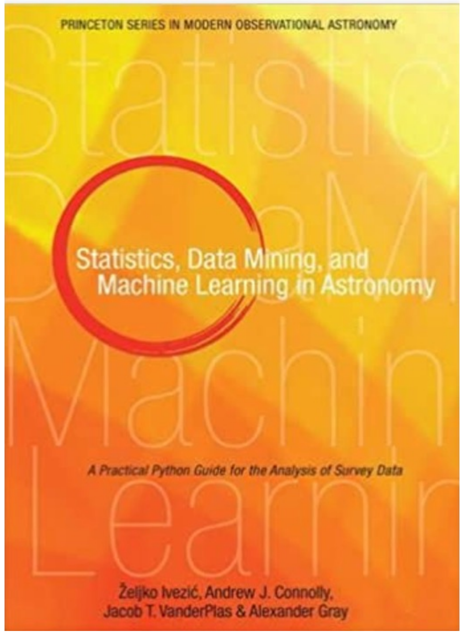
- We will post course announcements (any time), lectures (after class) and problem sets to the platform.
- Your homework should also be submitted to the platform, and the grade will be posted there as well.

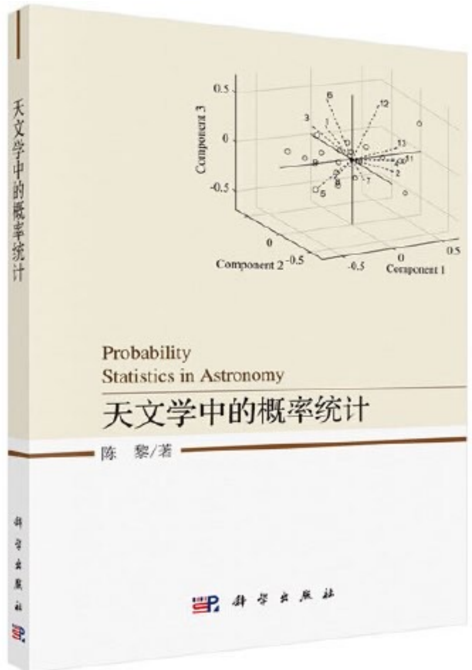
We can also use the discussion area in this platform, or more conveniently, the WeChat group:

Textbooks and references

The course material is developed from a variety of sources. There is no required textbook, but several books below are recommended for further reading, and some others will be mentioned in specific lectures.







See syllabus for more details.

Lectures

Lectures will be held at 9:50am-12:15pm on Tuesdays.

Location: Teaching building #3-1200

There will be NO online component; but special request will be considered.

Lecture format will be ppt slides augmented with occasional excursions on the blackboard.

There will be discussion points during the lectures, and you might be randomly named to share your thoughts.

We will post our lectures, but you are strongly encouraged to take notes.

Problem sets

There will be six problem sets assigned throughout the semester. They will be posted after the lecture, and are due two weeks later.

You should submit the homework through the web learning platform. Please pack them using .zip format, with the following naming convention:

2024310000_ZhangSan_HW2.zip

Grade with comments will be returned in 2 weeks.

A penalty of 10% lower grade per day will be incurred for late submission, except for special reasons.

*Some problems can be challenging: **don't start at the last moment**!*

Discussion/consultation with your peers are permitted, but the answers submitted must be the results of your own efforts.

Grading and exams

The final grade will be broken down into contributions from problem sets (65%), and a final take-home exam (35%).

Unless otherwise noted, we plan to distribute the final exam after the final lecture, and it will be due one week later (on Dec. 31st).

Grading will be based on the accuracy of the solution, the inclusion of intermediate steps, and communication of how the solution was found. When there is substantial coding, you are also required to attach your source code (<u>make sure they are well organized with comments</u>).

Course schedule

Dates	Content	Lecturer	Comments
9/10	Introduction; basic scientific computing	XB	
9/17	No lecture		
9/24	Interpolation/differentiation/integration	XB	
9/29	Numerical linear algebra I	XB	HW1
10/8	Numerical linear algebra II, Nonlinear systems	Zhuo Chen	
10/15	Optimization methods	XB	HW1 due; HW2
10/22	Ordinary differential equations	XB	
10/29	Partial differential equations	XB	HW2 due; HW3
11/5	Probability and statistical distributions	XB	
11/12	Classical statistical inference	XB	HW3 due; HW4
11/19	Bayesian statistical inference	DX	
11/23*	Monte Carlo method and Stochastic processes	DX	HW4 due; HW5
12/3	Model Regression	DX	
12/10	Fourier analysis and Application	DX	HW5 due; HW6
12/17	Data Structure and Classification	DX	
12/24	Applications	TBD	HW6 due

Dandan traveling;
Time/location TBD.

Course materials are dense, but you should find them very useful!