76^{th} Arthur H. Compton Lecture Series

Constructing the Solar System: A Smashing Success!

Lecture 1: A Star is Born

Thomas Davison

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Schedule for the 76^{th} Arthur H. Compton Lecture Series

1. 10/06/12 A Star is Born
2. 10/13/12* Making Planetesimals: the building blocks of planets
3. 10/20/12* *Guest Lecturer: Mac Cathles*
4. 10/27/12 Asteroids, Comets and Meteorites: Our eyes in the early Solar System
5. 11/03/12 Building the Planets
6. 11/10/12 When Asteroids Collide
7. 11/17/12 Making Things Hot: The thermal effects of collisions

   11/24/12 No lecture: Thanksgiving weekend
8. 12/01/12 Constructing the Moon

   12/08/12 No lecture: Physics with a Bang!
9. 12/15/12 Impact Earth: Chicxulub and other terrestrial impacts

*Please note, these two lectures may switch weeks at late notice

1 Introduction

1.1 About me

My background is in studying impact processes in detail. I began my research career during my masters degree by simulating impacts into the oceans, to help to explain why we see so few craters on Earth compared to other planets. During my Ph.D, I investigated impacts into high strength targets such as metals, comparing computer simulations with laboratory experiments. I then turned my attention to the early Solar System, to study the effects of collisions between the earliest solid bodies orbiting the Sun (1 – 100 km bodies called planetesimals) to gain some insight into the conditions in the very early Solar System. My research at the University of Chicago is continuing that investigation: our latest efforts have been to study the individual histories of the asteroids that we think were the parent bodies of many of the meteorites we find on Earth, to further our understanding of their thermal histories.

1.2 The lectures

In this lecture series, I will outline our current understanding of how the Solar System formed (including the Sun, the planets, and the asteroids). Impacts were one of the most fundamental processes during the construction and evolution of the Solar System. They were necessary events for the first solid particles to stick together and grow into ever larger objects, and eventually develop into planets. Impacts then went on to shape the planets, asteroids and moons that we observe today: Look at any object orbiting the Sun, and you will find evidence of collisions. Even here on Earth, collisions played a vital role in our development — from the formation of the Moon to the extinction of the dinosaurs. And yet, even after such a long, violent history, we are left with a planet in the Solar System capable of supporting life. Which, you could say, is **“A Smashing Success!”**

2 A model of the Solar System

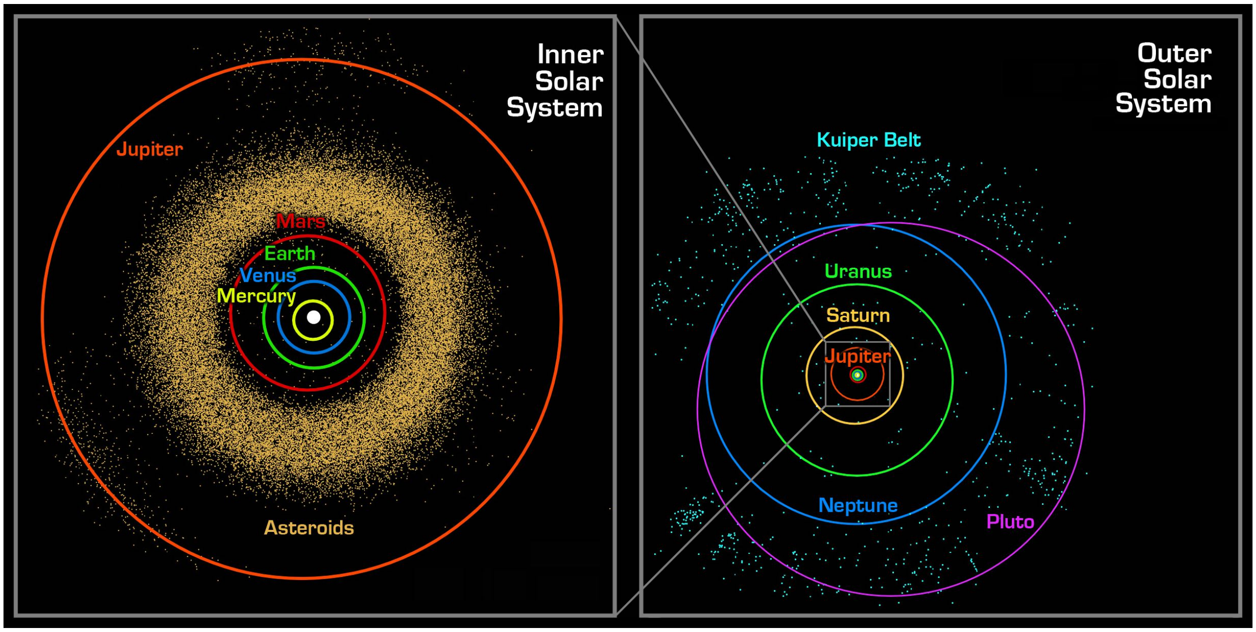

Figure 1: The orbits of the planets, asteroids and Kuiper Belt objects in our Solar System. The planets all have near-circular orbits, all orbit in the same direction around the Sun, and all their orbits lie on a similar plane. Image courtesy of NASA

During the course of the lectures, we will examine each step of the construction of the Solar System. However, there are some parts of the story where we don’t know for certain what happened. Why do we still have gaps in our knowledge of something so fundamental as the formation of the planets? The answer is that we have a very limited data set to build our model around:

- We have observations of the current structure of the Solar System (for example the size and orbital characteristics of the planets; see Figure 1)
- But to look back in time to see how things were billions of years ago is more tricky
  - Meteorites and asteroids (rocks that formed very early on, but were not incorporated into planets) can tell us something about what the early Solar System was like
- We have seen some examples of planet forming regions around young stars, but observing these is difficult

From these lines of evidence, our goal is to piece together 4.5 billion years of history.

3 Formation of the Sun

Our model of how the Sun formed must explain:

- Why the planets:
  - All have near circular orbits
  - All orbit in the same direction
  - All orbit in a similar plane
- Why the small, rocky inner planets are so different from the large, gaseous outer planets
- Why the Sun is:
  - At the center of this disk of orbiting planets
  - So much larger than any other object in the Solar System

The Sun formed from an interstellar cloud of gas and dust, called a *nebula*

- A local *overdensity* caused a region of the cloud to contract
- As this region contracted, it grew more dense
- As it grew more dense, it could attract more material because of its increasing gravity
  - This feedback loop is known as a *runaway process*
- The collapsing material converted gravitational potential energy to kinetic energy
  - Which was then converted to heat
- The contracting region became so hot that nuclear reactions began
  - The Sun was born as a star
- Conservation of angular momentum meant that as the cloud collapsed, its would have rotated faster and faster
- This led to a spinning disk of material surrounding the Sun (Figure 2)
  - If we assume that the planets formed from this disk, we have an explanation for why they all have similar orbital characteristics

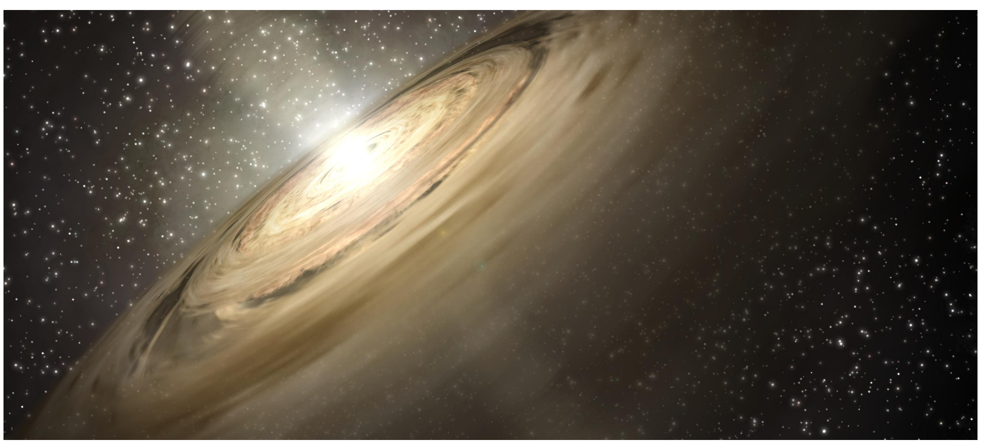

Figure 2: Artist's impression of a disk surrounding a young star. Image courtesy of NASA/JPL-Caltech

4 Next lecture

In the next lecture, we will discuss how the cloud of gas and dust surrounding the young Sun produced the first solid objects in the Solar System, and how they grew into planetesimals — the building blocks of planets.