CRLS Astrophysics Lecture Series
Introduction to Dynamics

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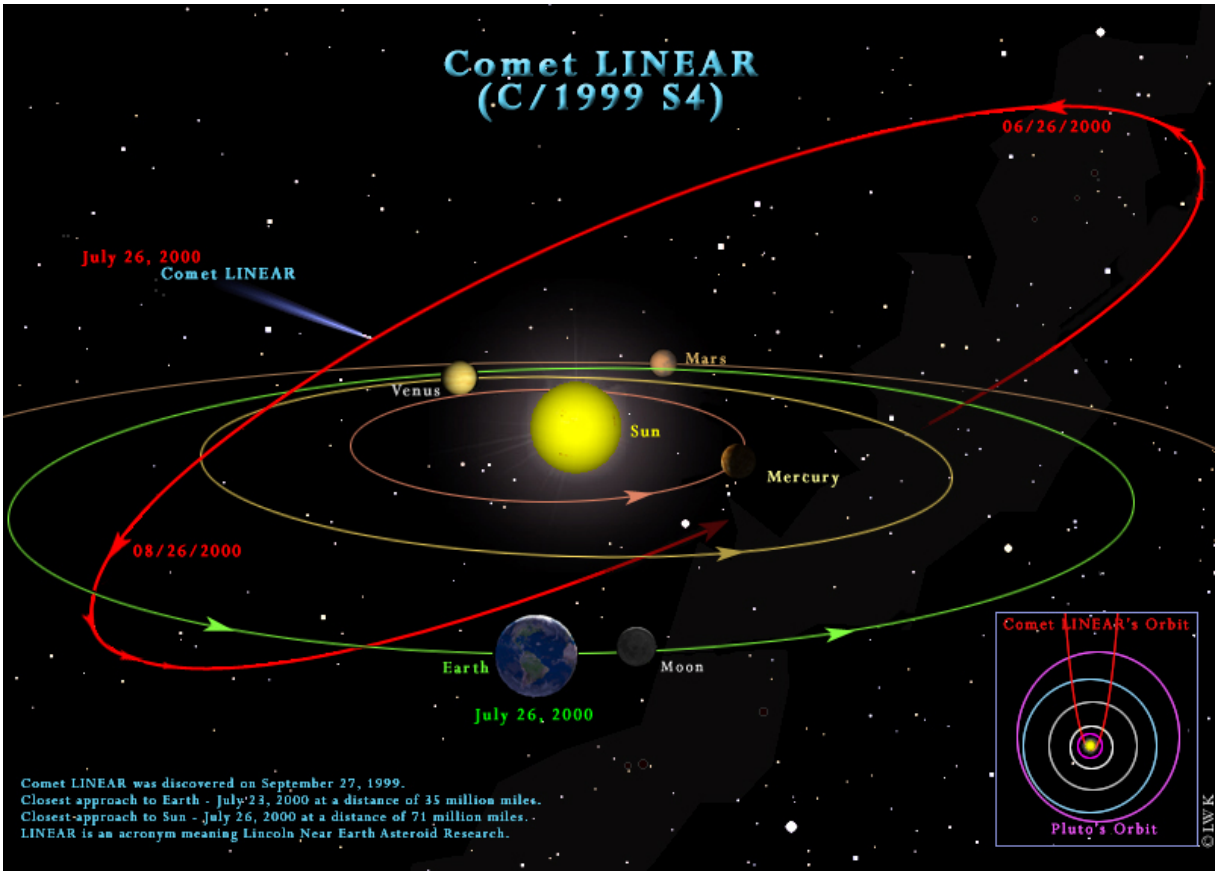

Figure 1: Our solar system is a dynamical laboratory.

Introduction

If you look up at the sky on a clear night, preferably someplace where there's little light pollution, (so away from Boston) you will see countless stars. There is both a beauty and motion to these stars. *But, what exactly produces these motions?* Such a question perplexed humanity for thousands of years, and was finally answered by Isaac Newton in 1687. Newton showed that the motion of the Earth around the Sun is due to gravity. Objects under the influence of forces, such as gravity, usually exhibit motion. The branch of physics that studies these motions is known as **dynamics**. In astronomy, we often call this branch celestial mechanics. The *Lunar Reconnaissance Orbiter* currently orbiting the Moon, the *Moon* orbiting the Earth, the *Earth* orbiting the Sun, the *Sun* orbiting the center of the Milky Way, the *Milky Way* which orbits the center of the Local Group of galaxies... the motion of all of these can be studied and understood through dynamics.

Goals

Our goal is to gain an understanding of the dynamical forces that help shape the Earth, the Sun, the Milky Way, and indeed the Universe as a whole. This is of course a LOT to take in! Much of what we will learn depends almost entirely on **gravity**. Therefore, much of the material below is to help you get acquainted with this mysterious force.

Reading Material

Your best bet to gain an understanding is to look over a basic astronomy or physics textbook. For example, a good description and discussion on gravity and Newton's laws can be found in *The Cosmic Perspective* which is an entry-level astronomy textbook suitable for high school students. That said, I realize that may not be possible, and there is plenty of online material. I recommend that everyone take a look and read/watch the material at the five webpages below. For starters a good overview of Newtonian gravity can be found here:
http://www.astronomy.ohio-state.edu/ pogge/Ast161/Unit4/gravity.html
If some of the math is confusing, do not worry about it. Understand what you can.

A slightly old, but still very nice NASA video on Newton's Laws can be found here:
https://www.nasa.gov/mov/192446main_016_intro_newton_laws.mov

Here is a wonderful video that covers some of the fascinating history:
http://www.history.com/topics/enlightenment/videos/beyond-the-big-bang-sir-isaac-newtons-law-of-gravity
Pay attention when they talk about "the Moon is in free-fall" -that is absolutely correct!

Here is a beautiful article on gravity by Nobel laureate George Gamow:
https://www.scientificamerican.com/article/gamow-gravity/
Here, we start discussing Einstein's version of gravity which differs from Newton's.

One of the most exciting discoveries in the past 50 years is the detection of gravitational waves:
https://www.nytimes.com/video/science/100000004200661/what-are-gravitational-waves-ligo-black-holes.html
Note that the orbit of the black holes is purely **dynamical**.

Here is some "fun" material:

20 Things You Didn't Know About... Gravity
http://discovermagazine.com/2013/julyaug/23-20-things-you-didnt-know-about-gravity

How Do Gravitational Slingshots Work?
https://www.youtube.com/watch?v=xJmD_1kSa3I

Physics test suggests cats understand gravity, Japanese researchers say
https://www.washingtonpost.com/news/morning-mix/wp/2016/06/16/physics-test-suggests-cafe-cats-understand-gravity-japanese-researchers-say/
Cats understand gravity? Do you?