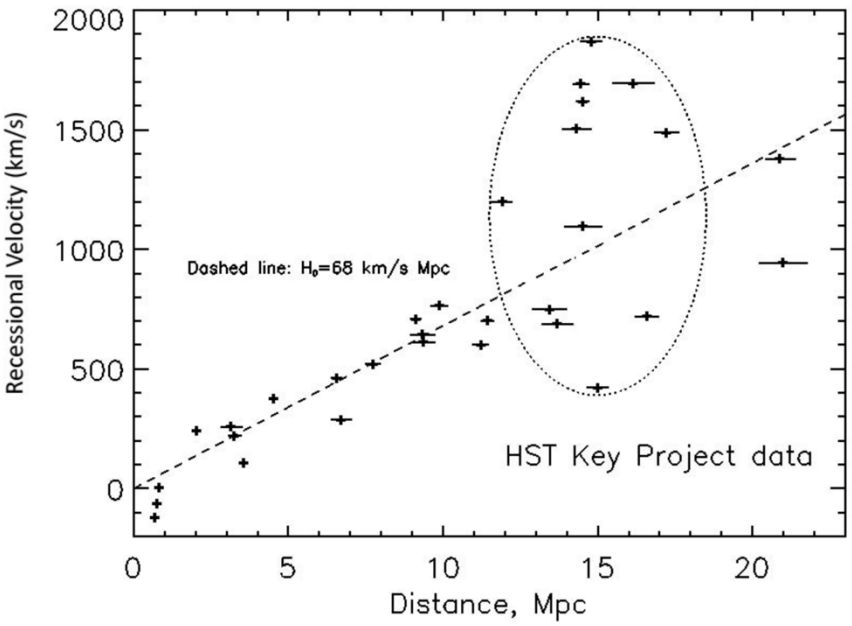
AST10C GE Sample Problem

Part I

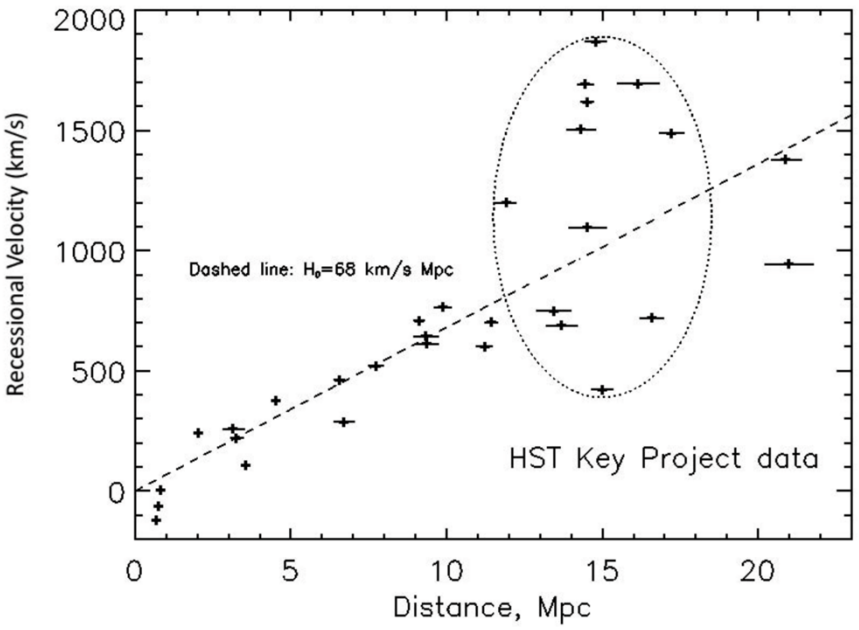
Hubble's Law Deviations Part I : Suppose you are measuring distances and recessional velocities of galaxies in order to test Hubble's Law, which is evidence for the expansion of the Universe. Based on these measurements, you produce the diagram shown here. Note that each point corresponds to measurements from a single galaxy. The small bars (referred to as errorbars) on each point in the X (Distance) and Y (Recessional Velocity) direction show the error or uncertainty in that particular measurement. The dashed line shows the prediction of Hubble's Law for a Hubble Constant H_0 = 68 km/s/Mpc. Based on this diagram, you find that most of the galaxies have velocities that are within 200 km per second (km/s) of the prediction of Hubble's Law. However, the galaxies that are circled in this diagram deviate significantly more from the prediction by up to 1000 km/s!



Given that the size of the errorbars are **smaller** than the velocity offsets from the prediction of Hubble's Law for most galaxies in this diagram, do you think that these offsets are due to measurement error or something physical? Explain your answer.

Part II

Hubble's Law Deviations Part II : Suppose you are measuring distances and recessional velocities of galaxies in order to test Hubble's Law, which is evidence for the expansion of the Universe. Based on these measurements, you produce the diagram shown here. Note that each point corresponds to measurements from a single galaxy. The small bars (referred to as errorbars) on each point in the X (Distance) and Y (Recessional Velocity) direction show the error or uncertainty in that particular measurement. The dashed line shows the prediction of Hubble's Law for a Hubble Constant H_0 = 68 km/s/Mpc. Based on this diagram, you find that most of the galaxies have velocities that are within 200 km per second (km/s) of the prediction of Hubble's Law. However, the galaxies that are circled in this diagram deviate significantly more from the prediction by up to 1000 km/s!



50% Part (a) Propose a hypothesis that would explain the galaxies with the largest deviations from Hubble's Law (the circled points), compared to those that are closer to the prediction.

50% Part (b) Outline a set of observations that you could use to test your hypothesis. When describing your observations make sure to include what wavelength range you would observe in and why (remember astronomers observe across the full electromagnetic spectrum!).

Rubric

Part I

- 50% for choosing the correct answer: that the offsets are due to something physical rather than measurement error
- 50% for stating that if the offsets were due to measurement errors, the offsets would have to be much smaller, since the error bars are small. An alternative statement that also conveys the idea that the scatter in the offsets is much larger than one would expect from the size of the error bars is also acceptable for the full 50%.

Part II (a)

- 30% for stating or clearly implying that offsets from the predictions of Hubble's Law must be due to the gravitational influence of other objects.
- 30% for stating or clearly implying that large offsets from Hubble's law must be due to large masses.
- 40% for proposing motions within galaxy clusters as the cause of the spread in the circled points

Part II (b) There are three possible observations that the student could propose, all of which would confirm a galaxy cluster if they showed the expected effect:

- Option 1: 50% for describing observations to look for overdensities of galaxies and 50% for mentioning that this would be at optical (visible) wavelengths
- Option 2: 50% for looking for emission from the hot gas in the cluster (the student does NOT have to mention the phrase "intracluster medium") and 50% for mentioning that this would use X-ray observations
- Option 3: 50% for suggesting that gravitational lensing could show the presence of a galaxy cluster and 50% for saying that these observations would be done at optical (visible) wavelengths