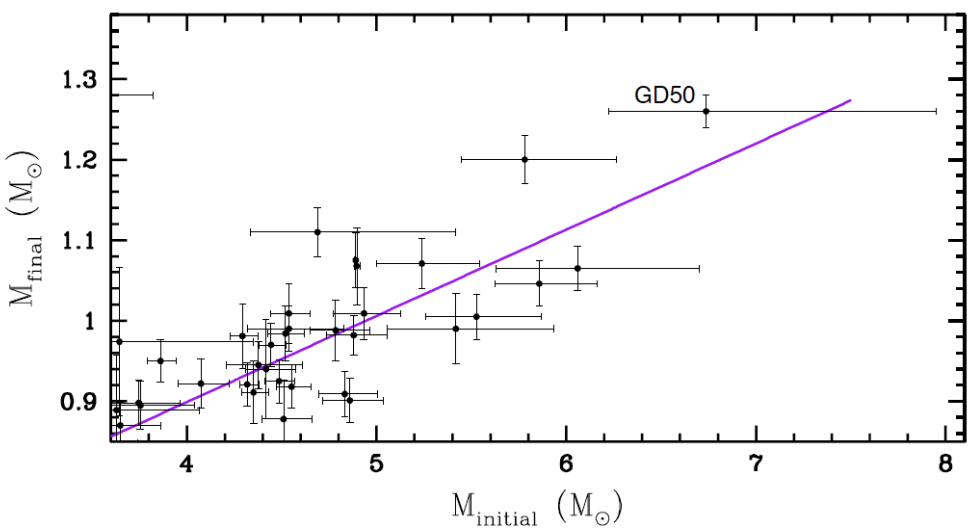
**Astronomy 205:**
**Assignment 4: Due April 1 2019 before class in ASTR205 Box outside Henn 312**
**Exploring the Properties of an Open Star Cluster and its White Dwarfs**

This assignment is a real research project. If it works out well we may be able to, as a class, publish a paper in an astronomy journal together. Here is the background to the project.

White dwarfs follow what is known as "The Initial-Final Mass Relation (IFMR)". What this means is that a star of a given mass on the main sequence will produce a white dwarf also of a given (but of course lower) mass. This relationship is VERY important in astronomy for quite a number of reasons: 1) the highest mass main sequence star on this sequence sets the lower limit for supernova production – this is thought to be in the range of 6-10 M_SUN. Stars more massive than the upper mass limit to produce a white dwarf will go supernova. 2) Supernovae control the energy and chemical enrichment of galaxies. 3) The supernova rate from massive stars (determined from the upper mass limit of main sequence stars forming white dwarfs) also determines the rate of formation of neutron stars and hence pulsars. There is more but this enough for our purposes. The current state of the art for the IFMR is shown in the plot below from a 2018 paper (pre Gaia).




What we will do in this assignment is the following.

1. Each of you will be given Gaia data in the direction of a young(ish) cluster that contains at least 1 white dwarf. The data will contain photometry for each star in the direction of the cluster (the G magnitude, and the (GB – GR) colour), the proper motion and the parallax.
2. Here you will attempt to show that the associated white dwarf(s) are members of the cluster. To accomplish this a) make a proper motion plot of all the stars in your sample. b) Select out the stars that form a tight clump in proper motion space. This will potentially be your cluster star sample. c) Make a histogram in number of stars versus parallax. This should look rather Gaussian. d) Make a 2-sigma cut in this histogram and plot the stars that make the cut in an HR diagram. e) Note the number of white dwarfs that you have in this diagram. f) There may be some obvious outliers here (stars away from the usual sequences in a young cluster). Eliminate them from your files and make another Gaussian plot. Include your white dwarf(s) in this plot with a different colour. Have all your white dwarfs made the cut?

3. Correct your data for extinction and reddening. Some stars in your data set have extinction and/or reddening data, and you should use this information to develop values of each parameter for the entire cluster. Individual reddening values are usually fairly uncertain, so don't assume that any individual measurement is very accurate. Only including cluster members, average the values provided to create a value for the cluster as a whole, and apply the result to your CMD.
4. You are given a file of isochrones of various ages (gaia_isochrones.dat – you will want the last 3 columns in this file). Plot the best fitting one on your extinction and reddening-corrected CMD (after a bit of experimentation). In this way, determine the age of your cluster from the turnoff.
5. From the isochrones also determine the turnoff mass of your cluster (masses are in the fourth column of the isochrone file).
6. Using the files Table_Mass_0.x (0.x refers to the mass of the white dwarf in solar masses), find the best fitting white dwarf cooling sequence that passes through the position of your white dwarf(s). This gives you a mass for your white dwarf(s).
7. From the theoretical white dwarf cooling sequences, estimate the cooling time of your white dwarf.
8. Subtract the white dwarf cooling time from the age of your cluster. This will give you the main sequence lifetime of the white dwarf precursor. Determine then the mass of the white dwarf precursor when it left the main sequence.
9. Plot this point in a diagram similar to the above Initial-Final Mass Relation and report the mass of your white dwarf and its precursor mass. It is important to provide error estimates of your initial and final masses.
10. When the assignments are handed in Ronan and I will plot all the results and see if we improve on the scatter in the figure above.