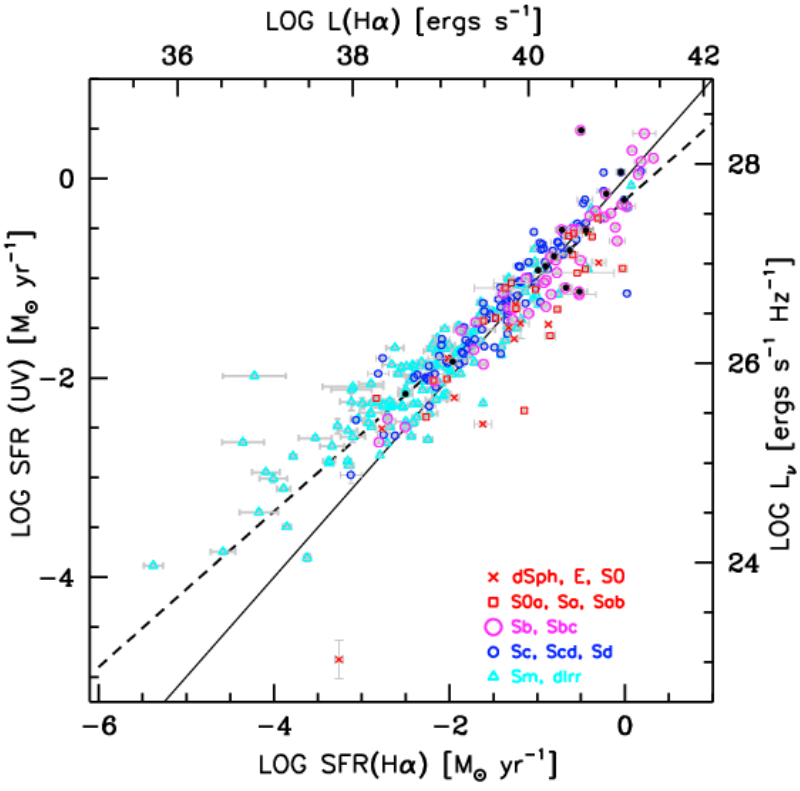
Problem Set #5: Active Galaxies & Dark Matter

Due: Tuesday, November 10 by 5pm to Dickinson 104

1. Starburst galaxies range in star forming rates from a few solar masses per year all the way up to 100 or 1000 solar masses per year. For each of the following starburst galaxies, estimate the time until they will use up their available gas for star formation. There is no single "right answer" to these problems; a lot of it depends on your assumptions. You should make these assumptions based on what you read in the book and any outside reading that you can do. Make sure your assumptions are reasonable and clearly stated. Masses given below are total galactic masses (stars+ISM+dark matter). Things to consider in making assumptions: (1) gas mass fraction (2) what fraction of that gas mass is available for star formation (3) how fast this gas is likely to be used up by star formation.
    a. HXMM01 is a distant starburst galaxy with a star formation rate of near 2000 $M_\odot$/yr. The galaxy has roughly 10 times the mass of the Milky Way.
    b. M82 is a starburst with an Hα flux of 8.1×10^{-11} erg/s/cm^2 and a mass of 3×10^8 $M_\odot$. (*Hints: you can easily find the distance to M82 in any standard catalog. You will need to use that and the Figure below.)*



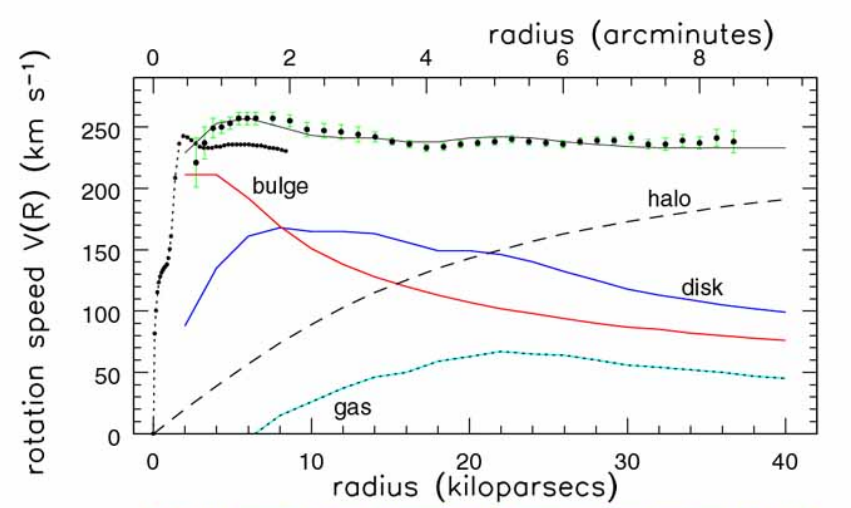
Comparison of observed FUV and Hα SFRs calculated using the linear conversion recipes given in Kennicutt (1998).

2. NGC 1569, a nearby dwarf starburst, was recently forming stars at a rate of nearly 100 $M_\odot$/yr and a mass of 3×10^8 $M_\odot$. Given that this galaxy has stars of a large range of ages (~13 Gyr to present day), carry out a simple calculation to explain why star formation in dwarf galaxies like this must be "bursty."

3. Show that 10^{12} $L_\odot$ corresponds to an energy output of 0.1 $M_\odot c^2$ per year. As they age, stars like those in the solar neighborhood eject about 1 $M_\odot$ per year of gas for each 10^{10} $L_\odot$ of stars. If all the gas lost by stars in our Galaxy could be funneled onto the black hole in the center of our Galaxy, and 10% of its mass released as energy, how luminous would the Milky Way's nucleus be? How does this compare to the luminosity of the rest of the Milky Way?

4. An astronomer observes a point-like X-ray source that shows significant variation in brightness over an interval of 12 hours. Follow-up observations at optical wavelengths show that the X-ray source is coincident with the central region of a spiral galaxy. Spectroscopic measurements reveal that the central region of the galaxy emits a broad Hα emission line at a wavelength of 665.8 nm. These measurements also show strong, narrow forbidden lines. An observation at radio wavelengths shows that the radio luminosity of this source is similar to that of a normal spiral galaxy.
    a. Calculate the maximum radius of the X-ray source. Express your answer in terms of astronomical units (AU).
    b. Calculate the redshift and hence the distance of this galaxy. Express the distance in terms of Mpc. (Note that the emission wavelength of Hα is 656.3 nm.)
    c. On the basis of the information given here, what type of object is this? Be as specific as you can, and explain your reasoning.

5. Consider the rotation curve for the spiral galaxy NGC 7331:



a. Find the total mass of NGC 7331 within R=37 kpc and show that the ratio M/L~10 in solar units (This is considerably higher than the value M/L~3 found for the gas and stars of the Galactic disk near the Sun).

b. *Using only the figure above,* determine the distance to this galaxy (*Hint: Examine the axes of the above graph carefully*).