ASTRONOMY 51/151 - SPRING 2022
Exercise Sheet 8
DUE by Thursday, May 11, 2022
300 points

Extraction of the Rotation Curve of a Galaxy - Part III

In Part II, you constructed the velocity map of the galaxy. In this Part III, the goal is to construct the velocity curve ($v_c(r)$) as a function of galacto-centric distance r. Ultimately, you will want to derive and plot $v_c(r)$ (in units of km s^{-1}) versus r (in units of kpc).

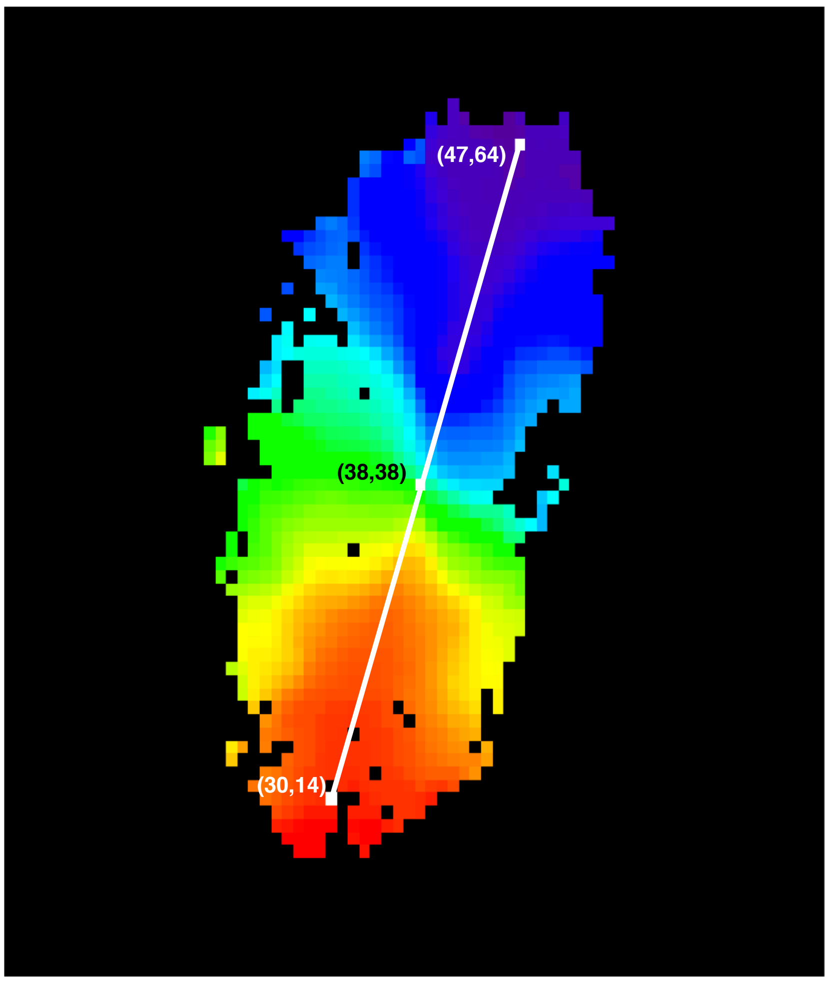

Figure 1: Velocity map with the major axis (thick white line) along which the line-of-sight velocity profile $v_{\rm los}(s)$ must be extracted.

In order to derive the $v_c(r)$, the following steps must be performed:

1. The line-of-sight velocity profile $v_{\rm los}(s)$ must be extracted along the major axis of the galaxy at different position s. The major axis of the galaxy is shown in Figure 1

as a thick white line. A rough center of the galaxy is at the fiber (38,38). You must make a figure showing $v_{\rm los}(s)$ [km s^{-1}] as a function of s [arcsec]. *Tips:* I advise to first derive $v_{\rm los}(s)$ [km s^{-1}] as a function of s along the white line plotted in Figure 1 *in units of pixels*; once you have $v_{\rm los}(s)$ [km s^{-1}] versus s [pixel], it is trivial to obtain s [arcsec] by multiplying s [pixel] times the pixel scale, which is 0.5 arcsec pxl^{-1}. To derive $v_{\rm los}(s)$ [km s^{-1}] versus s [pixel], you will have to extract $v_{\rm los}(s)$ from the previously derived velocity map at equally separated points along the white line in Figure 1. Therefore, first you need to derive the equation of the thick white line using the two coordinates written in white; then, you will want to sample the white line from $Y_{\rm fiber} = 10$ to $Y_{\rm fiber} = 65$ (or from $X_{\rm fiber} = 29$ to $X_{\rm fiber} = 47$) in steps of $\Delta s = 1.5$ pixel *along the white line*. In order to do so, you will need to interpolate over a 2-dim grid (the velocity map previously derived). When you extract the velocity $v_{\rm los}(s)$ [km s^{-1}] as a function of s [pixel] along the white thick line, don't forget to also extract the error of the $v_{\rm los}(s)$ [km s^{-1}]. Produce a figure showing $v_{\rm los}(s)$ [km s^{-1}] versus s [pixel], with the errors on $v_{\rm los}(s)$.

2. the extracted $v_{\rm los}(s)$ must be folded (by making the assumption that the rotation curve is symmetric about the folding center). In order to find the folding center, you will fit $v_{\rm c}(r)$ with the function

$$y = \frac{a-d}{1+(x/c)^b} + d, \tag{1}$$

where a, b, c, and d are the free parameters. The folding center in the position is given by $s_{\rm center} = c$, whereas the folding center in the velocity position is given by $v_{\rm los,center} = (a+d)/2$. *Tip:* For this fitting step, I advise you to weight all the points equally (rather than by their corresponding errors on $v_{\rm c}(r)$); to do so, build a "fake" velocity error vector equal in dimension to the previously derived velocity error vector, but with all elements being 0.1 km s^{-1}. Use this "fake" velocity error vector in the fitting step to find the folding center. Make a figure showing $v_{\rm los}(s)$ [km s^{-1}] versus s [pixel], with the errors on $v_{\rm los}(s)$, and overplotted the best-fit function. After you find the folding center, you fold one arm on top of the other. You must construct a third figure showing the two arms folded on top of each other. Make two versions of this figure, one showing the folded arms as a function of s [pixel], and the other as a function of s [arcsec]

3. At this point, you can obtain the velocity curve using $v_{\rm c}(r) = v_{\rm los,folded}/\sin i$, where $i = 65.065$ deg is the inclination of the galaxy, and $r = s$. Make sure that you also change the units of the x-axis from arcsec to kpc. You must produce a figure showing the actual rotation curve, i.e., $v_{\rm c}(r)$ [km s^{-1}] as a function of r [kpc].