Rotational speeds of stars

The rotational speeds may be understood through a simple calculation. There are spiral galaxies (like our Milky Way) in which the stars orbit around a centre where much of the mass is concentrated—called the galactic bulge. The rotational (centripetal) force equals the gravitational force. So, for a star of mass m moving with velocity v at a distance r from the centre of the bulge, we have

$$\frac{mv^2}{r} = G\frac{Mm}{r^2}.$$

Here G is the gravitational constant and M is the mass enclosed inside the distance r. Solving, we get the rotational speed to be

$$v = \sqrt{\frac{GM}{r}}\ .$$

So the speed should decrease inversely as the square root of the distance from the centre as you go far away from the bulge. This is what every one expected, and what is shown in the figure.

On the other hand, if the star is still inside the bulge, then the mass enclosed inside the radius r depends on the (approximately constant density ρ of matter inside: $M = 4\pi r^3\rho/3$. In such a situation the rotational speed is approximately given by

$$v = \sqrt{\frac{G\ 4\pi\rho}{3}}\ r\ ,$$

and this is proportional to r, close to the centre. Hence the rotational speed close to the centre increases linearly and then decreases as you go farther away from the galactic centre.

[Also see the article on Dark Matter in Jantar Mantar, July-August 2013]