On the variation of the energy scale 24

Rotation curves for gas-dominated dwarf galaxies

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Summary

Sanders (2018) has suggested that the rotation curves of gas-dominated dwarf galaxies provide a good test for theories of dark matter and modified dynamics. Four of the twelve galaxies studied by Sanders are in the SPARC catalogue and good fits to their rotation curves are generated by the JoKe equation:

$$\boldsymbol{v}^2(\boldsymbol{r}) = \frac{\boldsymbol{G}}{\boldsymbol{r}} \int_{x=0}^{r} \left\{\frac{\boldsymbol{r}}{\boldsymbol{x}}\right\}^{\boldsymbol{\alpha}} \boldsymbol{dM}(\boldsymbol{x})$$

This equation is fully explained in JoKe22 (2019).

1 Introduction

1.1 There are many theories for explaining the flat rotation curves of disk galaxies. The current favourites invoke the hypothesis of dark matter, which itself is made up of hypothetical particles beyond the standard model such as WIMPs or axions or sterile neutrinos.

1.2 There is a minority in favour of theories that modify the way that gravity works. Chief amongst these is modified Newtonian dynamics (MOND), with the hypothesis that gravity behaves differently under the very low accelerations that occur in the outer regions of disk galaxies.

1.3 The mass of the stellar contribution depends on measuring the light emitted and a knowledge of the mass-to-light ratio, which is not well-determined. The mass of the gas contribution depends on 21-cm radio observations, which are better understood.

1.4 This means that the mass of disk galaxies are best determined for galaxies that are dominated by gas and have only a small proportion of stars. These, gas-dominated galaxies, are therefore better test beds for theories that claim to explain rotation curves.

1.5 Sanders (2018) examined 12 gas-dominated dwarf galaxies and showed that their rotation curves are explained comprehensively by the modified dynamics of MOND.

1.6 JoKe22(2019) showed that the conjecture that the energy scale can vary from location to location leads to the following equation for the rotation curve of disk galaxies:

$$\boldsymbol{v}^2(\boldsymbol{r}) = \frac{\boldsymbol{G}}{\boldsymbol{r}} \int_{x=0}^{r} \left\{\frac{\boldsymbol{r}}{\boldsymbol{x}}\right\}^{\alpha} \boldsymbol{dM}(\boldsymbol{x}) \tag{1}$$

where $\boldsymbol{dM}(\boldsymbol{x})$ is the increment in mass. The $\boldsymbol{\alpha}$ exponent is the only adjustable parameter.

1.7 JoKe22 (2019) showed that equation (1) provides good fits to a sample of 64 disk galaxies in the SPARC catalogue (Lelli et al, 2016).

1.8 Four of the galaxies in the SPARC catalogue are among the twelve examined by Sanders (2018). These four galaxies are examined in this paper using equation (1).

2 Four gas-dominated SPARC galaxies

2.1 The next pages show the results of applying equation (1) to four galaxies from the SPARC catalogue (Lelli et al, 2016). These are all gas dominated and analysed by Sanders (2018).

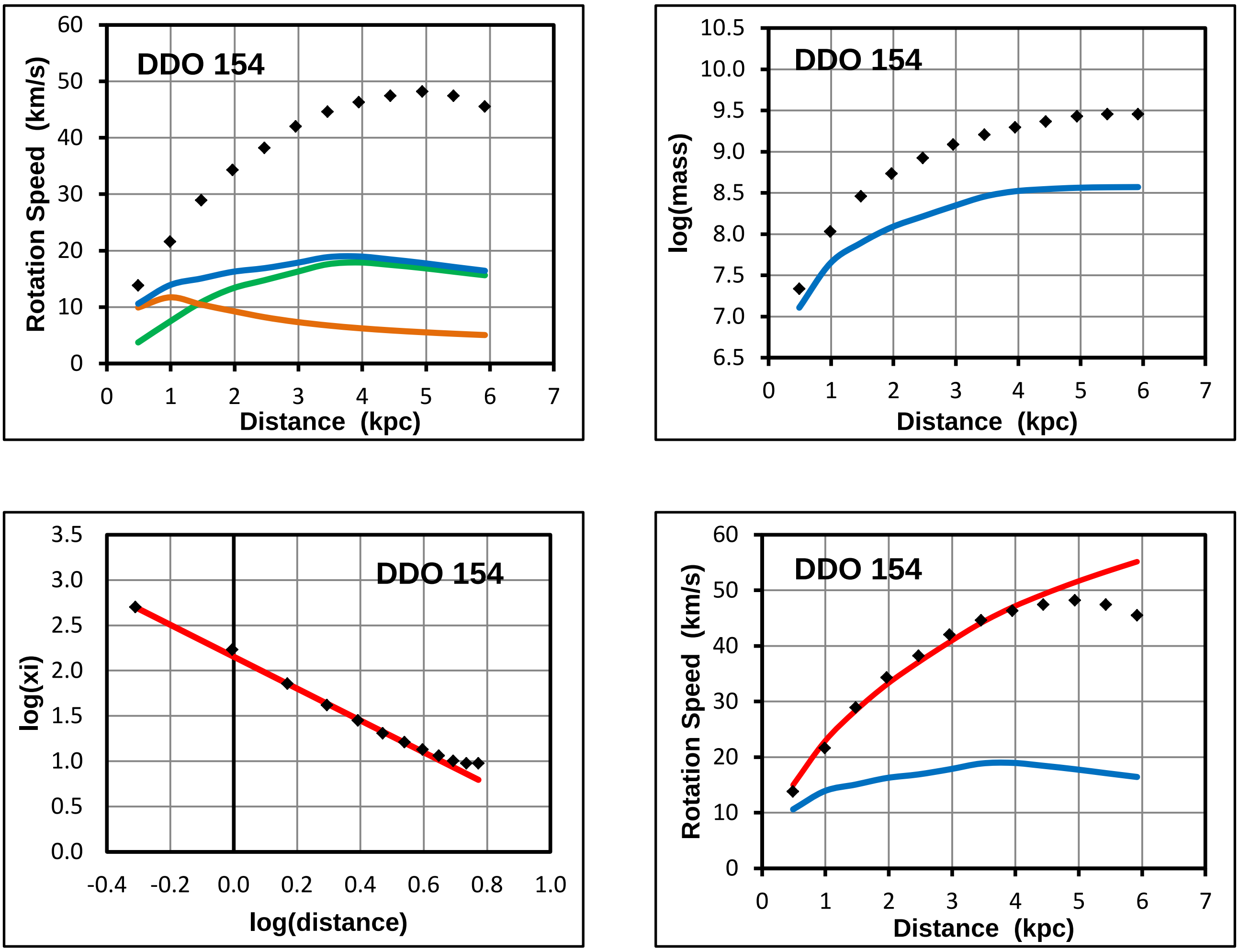
2.2 The top left panel shows the SPARC data. The black diamonds are the observations of the rotation curve. The orange curve is the contribution to the velocity from the disk of stars; the green curve from the gas. The blue curve is the expected velocity given by aggregating the components using equation (10) in JoKe22 (2019).

2.3 The top right panel shows the cumulative mass distribution corresponding to the velocities in the top left panel. The values are found by solving the numerical form of equation (5) in JoKe22 (2019). The black diamonds give the observed total mass corresponding to the black diamonds in the top left panel. The blue line gives the normal matter mass corresponding to the blue line in the top left panel.

2.4 The bottom left panel shows, in logarithmic form, the ξ-function as a function of distance, as derived by solving equation (4) in JoKe22 (2019). The black diamonds correspond to the observed velocities shown in the top left panel. All galaxies show an approximate linear relation. The red line is a straight line that approximates to the observed data. The negative of the slope is the α exponent of equation (1).

2.5 The bottom right panel shows the rotation curve again. The black diamonds are the same observed velocities as in the top left panel. Similarly the blue line is the same expected velocities as in the top left panel. The red line is the fitted rotation curve derived by applying the red line from the bottom left panel for $\xi(x)$ to the blue line from the top right panel for the mass $dM(x)$. The fitted velocity is calculated by applying the $\xi(x)$ and $dM(x)$ to equation (1).

DDO 154



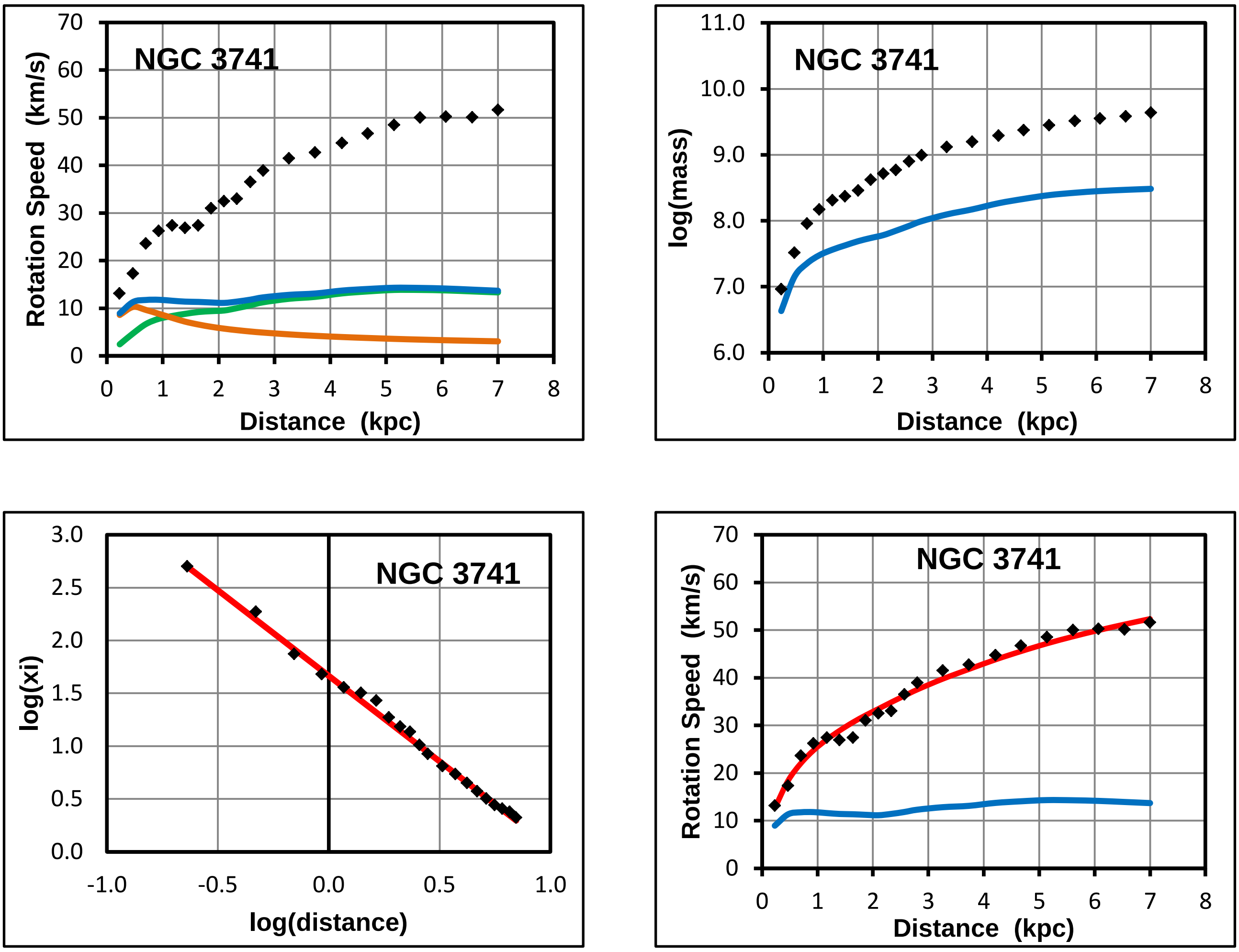
Top left: rotation curve from SPARC data
Top right: cumulative mass
Bottom left: ξ-function
Bottom right: fitted rotation curve

Fit parameters

ϒ, M-to-L	0.65
ξ, slope	-1.76
DM factor	6.7
Fit quality	good

Comments:
Fit excludes outer 3 data points because ξ-function is levelling off.

NGC 3741



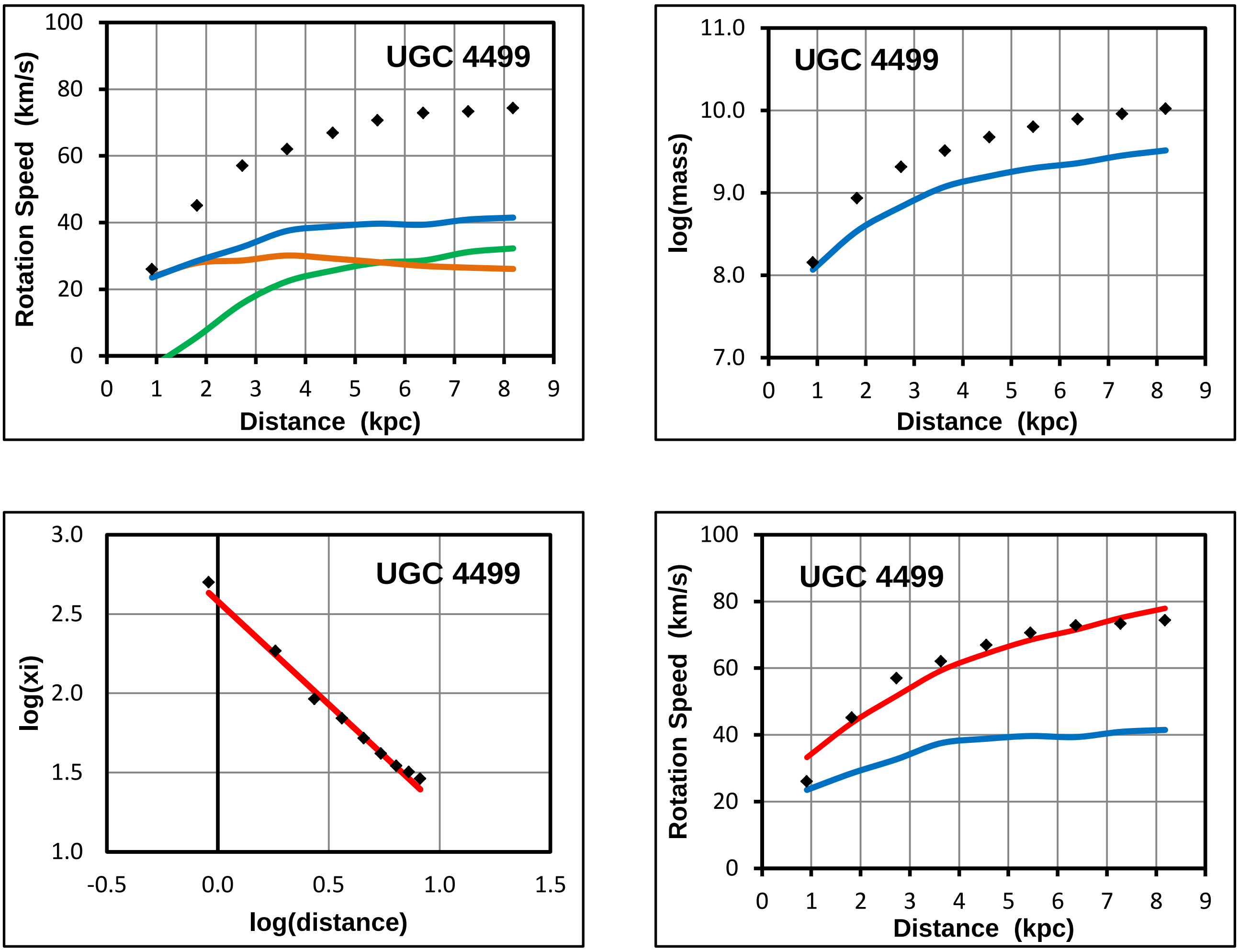
Top left: rotation curve from SPARC data
Top right: cumulative mass
Bottom left: ξ-function
Bottom right: fitted rotation curve

Fit parameters

ϒ, M-to-L	0.55
ξ, slope	-1.62
DM factor	13.2
Fit quality	good

Comments:
Galaxy is gas dominated from 1kpc.

UGC 4499



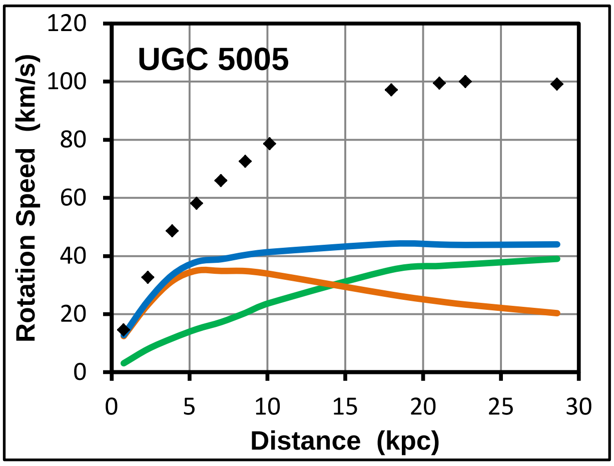
Top left: rotation curve from SPARC data
Top right: cumulative mass
Bottom left: ξ-function
Bottom right: fitted rotation curve

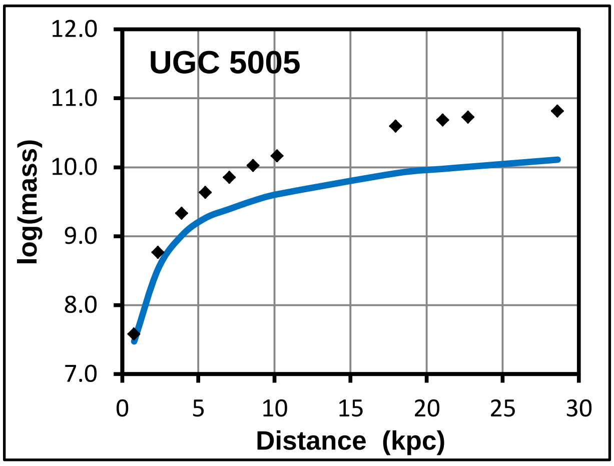
Fit parameters

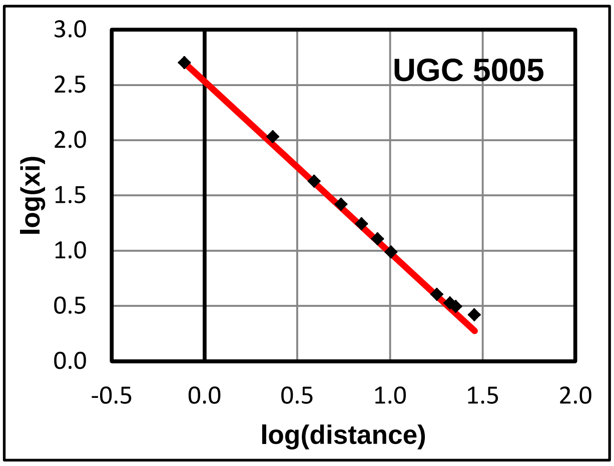
ϒ, M-to-L	0.62
ξ, slope	-1.30
DM factor	2.2
Fit quality	OK

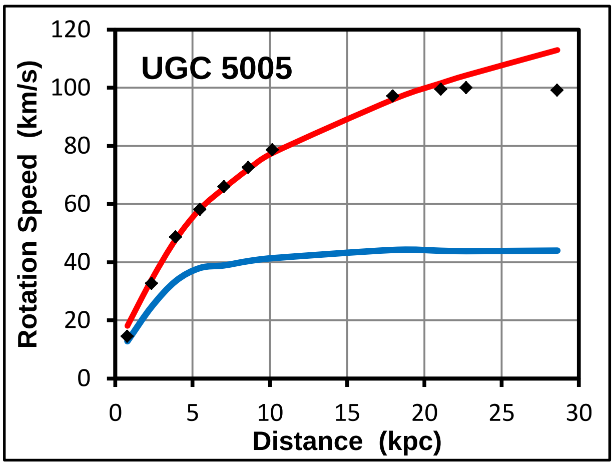
Comments:
Galaxy is gas dominated in outer regions. Mass has not converged.

UGC 5005









Top left: rotation curve from SPARC data
Top right: cumulative mass
Bottom left: ξ-function
Bottom right: fitted rotation curve

Fit parameters

ϒ, M-to-L	0.62
ξ, slope	-1.55
DM factor	4.1
Fit quality	good

Comments:
Galaxy is gas dominated from 15kpc.
Mass has not converged and is still increasing at 29kpc.
Fit omits outer 2 data points because ξ-function shows signs of levelling off.

3 Discussion

3.1 Good fits are obtained for the rotation curves of all four galaxies. The fits are at least as good as those obtained by Sanders (2018) using the modified dynamics of MOND.

3.2 The fitted rotation curves are obtained by using equation (1) with the actual masses, $dM(x)$, as provided by the SPARC catalogue. No approximations or functional forms have been used; the actual masses have simply been plugged into equation (1) directly and without modification.

3.3 Of the four galaxies, DDO 154 and NGC 3741 are particularly noteworthy as they are completely gas dominated. The stellar disk is important only in the innermost part of the galaxies.

3.4 This paper supports the ideas put forward in JoKe22 (2019) and demonstrates that equation (1), and by extension the conjecture of energy scale variations, is fully capable of explaining the observed rotation curves of disk galaxies. It follows that there is no requirement for any dark matter in disk galaxies.

4 References

JoKe22. (2019). "On the variation of the energy scale 22: An analysis of SPARC galaxies". **www.varensca.com**

Lelli, L; McGaugh SS; Schombert JM. (2016). "SPARC: Mass Models for 175 Disk Galaxies with Spitzer Photometry and Accurate Rotation Curves".
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