Comparing the new MOG theory with dark matter approach in extragalactic context

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The Galactic rotation curve

Distribution of dark matter in Universe is a long-standing problem of astrophysics and cosmology. Rotation curves of galaxies are considered to be an important source of information on mass distribution within the galaxies. The distribution of mass determines the orbital evolution of individual objects moving in the galaxies. Flat rotation curves of galaxies belong to one of the most significant observations supporting dark matter theory.

Modified Gravitation

A new MOdified Gravitational theory (MOG) based on the observational results of McGaugh et al. [5] was proposed by Klačka et al. [2], [3]. The theory suggests a modified centripetal acceleration relation in the form

$$g_{obs} = \frac{g_{bar}}{1 - \exp - \sqrt{g_{bar}/g_{\dagger}}} \, . \qquad (1)$$

where $g_{bar} = \mathrm{d}\Phi_{bar}/\mathrm{d}R$ and $g_{\dagger} = 1.2 \times 10^{-10}$ m s^{-2}. The circular velocity based on Eq. 1 yields

$$v_c(R) = \sqrt{\frac{R\xi}{1 - \exp\left(-\sqrt{\frac{\xi}{g_{\dagger}}}\right)}} \, . \qquad (2)$$

where $\xi = \partial(\Phi_{Total-DMhalo})/\partial R$ is the potential contribution with the component of the dark matter halo omitted.

Galaxy sample

The SPARC catalogue [4] is a database of 175 spiral and irregular galaxies with high-quality rotation curves. We compared the new theoretical results (Eq. 2) and the standard dark matter approach with the rotation curves of 9 SPARC galaxies.

ID	Type	$\log(\frac{M_{bar}}{M_\odot})$	$e(M_{bar})$	a_{bar}	$\log(\frac{M_{DM}}{M_\odot})$	$e(M_{DM})$	a_{DM}
ESO563-G021	Sbc	11.40	±0.065	8	12.93	±0.255	90
NGC 2841	Sb	11.00	±0.045	3	12.54	±0.135	80
NGC 3198	Sc	10.53	±0.055	5	11.67	±0.070	90
NGC 5055	Sbc	10.96	±0.050	4	11.82	±0.030	90
NGC 5985	Sb	11.08	±0.120	5	12.21	±0.080	90
NGC 6503	Scd	9.94	±0.045	2.5	11.28	±0.070	90
UGC 02953	Sab	11.18	±0.120	4.4	12.29	±0.070	14
UGC 03205	Sab	10.94	±0.075	2.5	12.12	±0.190	90
UGC 11455	Scd	11.22	±0.100	9.5	12.61	±0.200	30

Potential models

We described the potential of the baryonic matter with a simple Plummer model, while the model of Allen & Santillan [1] was assumed for the dark matter halo, both shown in Eq. (3). All the selected galaxies had well-determined baryonic and dark matter masses.

$$\Phi_{\text{halo}}(r) = \frac{-GM_{\text{halo}}}{r} - \frac{GM_{\text{halo}}}{1.02 a_{\text{halo}}} \left[\frac{-1.02}{1 + (R/a_{\text{halo}})^{1.02}} + \ln\left(1 + \left(\frac{R}{a_{\text{halo}}}\right)^{1.02}\right) \right]_{R=r}^{100} ,$$
$$\Phi_{\text{Plummer}}(r) = \frac{-GM_{\text{bar}}}{\sqrt{r^2 + a_{bar}^2}} \, . \qquad (3)$$

Results

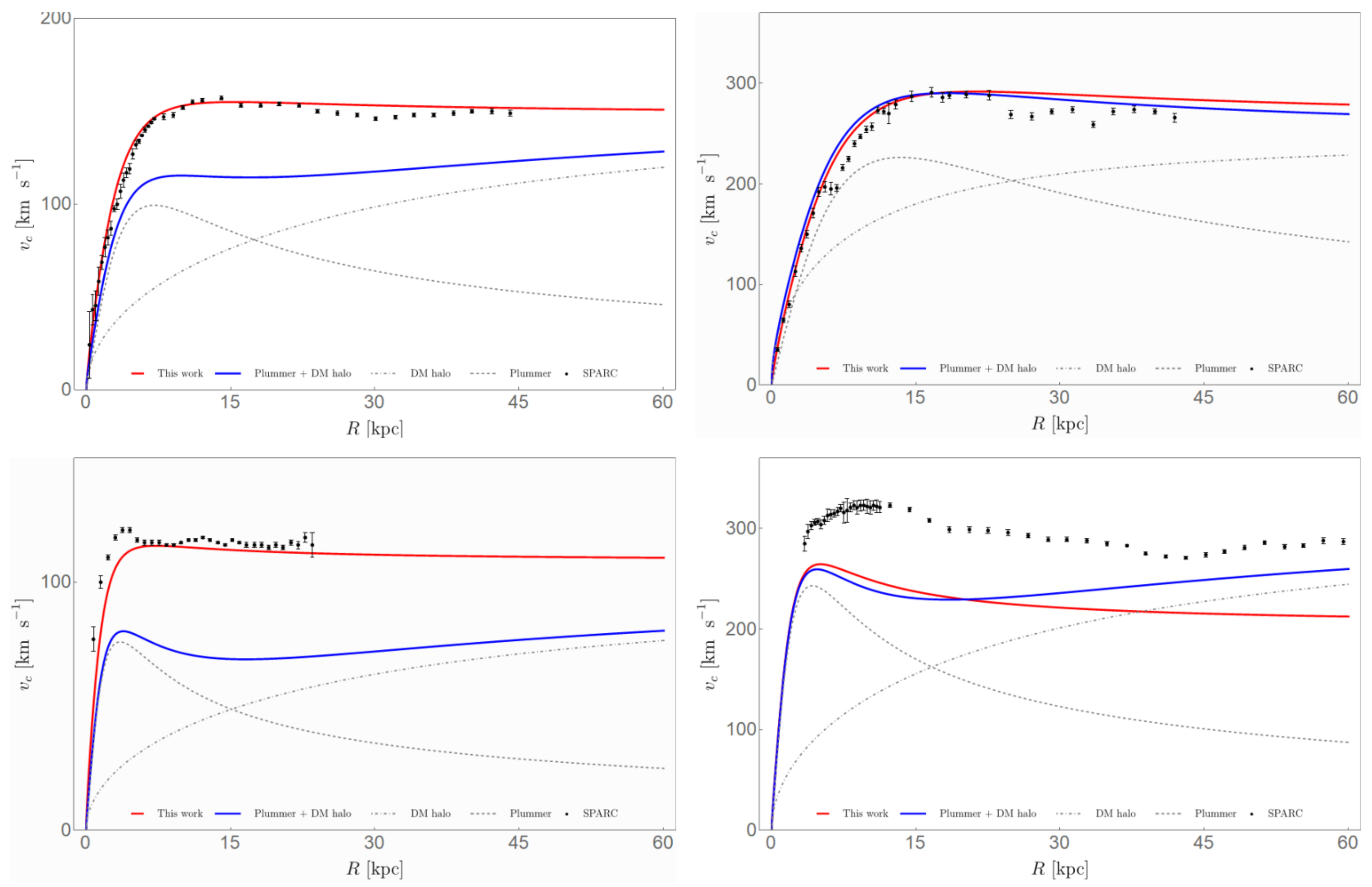

Fig. 1: Different results. Left: better fit with the new MOG theory, top: NGC 3198, bottom: NGC 6503. Top right: well-fitted by both approaches, UGC 11455, bottom right: neither of the approaches fit the data, NGC 2841.

Our results imply, that from the selected sample of galaxies (i) 33 % could be fitted with the new MOG theory, (ii) 44 % could be fitted by both approaches and (iii) 23 % was not fitted well with any of the two approaches. All of the selected galaxies are spirals. This couldn't be the cause of the different results. However, the determined masses of the galaxies might have uncertainties due to inclination of the galactic planes, therefore, masses could not be calculated reliably from the M/L ratios. Also, we neglected the galactic components such as the disks, bulge, spiral arms or the stellar halo and we only considered that all the galactic mass is almost spherically symmetrical, therefore we only used a simple Plummer model.

Remarks

Figure (2) shows the rotation curve of the NGC 3198 galaxy and it's consistency with the theoretical rotation curve of the new MOG theory.

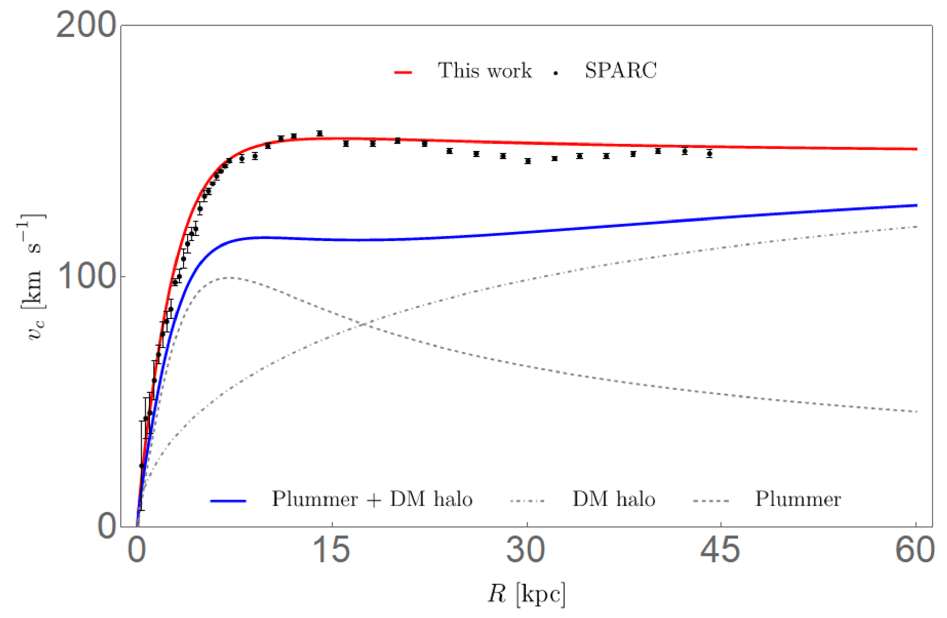

Fig. 2: Rotation curve of the NGC 3198 galaxy.

As we stated, we obtained three different results. However, this might be because of the uncertainties of the determined masses of the galaxies. Our goal was to show, that the new MOG theory proposed by Klačka et al. [2], [3] is able to provide satisfying results when applied to observational data. This goal was achieved, as the results of the new MOG theory are similar or in some cases better than the approach with the use of the dark matter halo. However, further confrontations with the observational data are needed.

Acknowledgements

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