On Cosmic Filaments, Dark Halos and Rotation Curves

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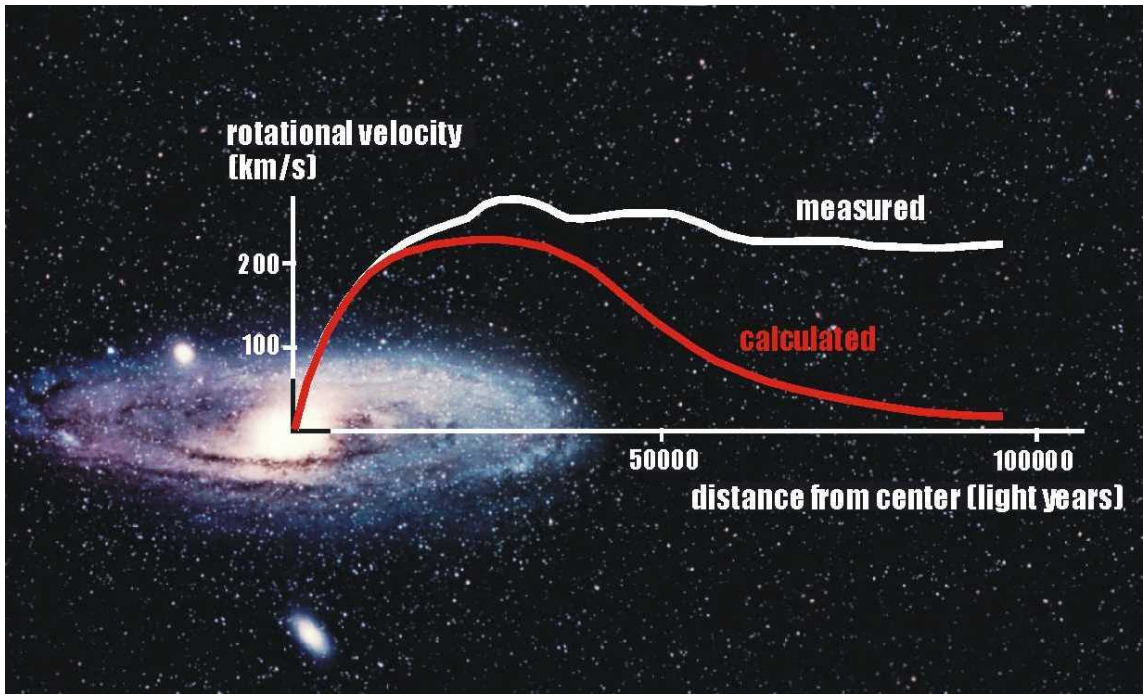
Dark Matter

- $\sim$ 85% of matter in the Universe is comprised of unknown substance
- Key piece of evidence: "flattened" galaxy rotation curves $\Rightarrow$ effective log–potential at large distances



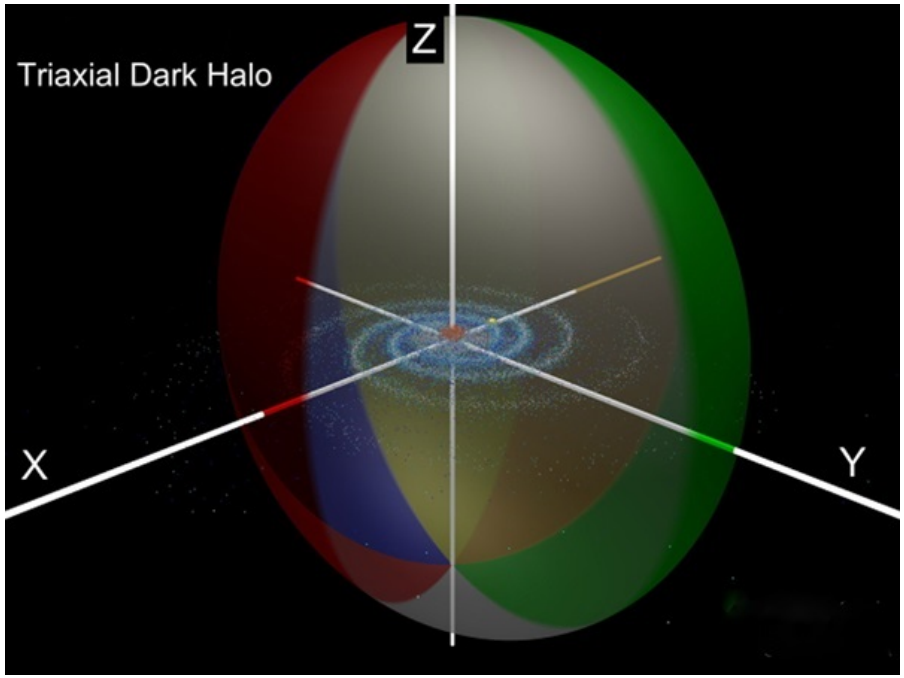
Simple Geometric Idea from Electrostatics

Infinite charged line/cylinder yields log–potential:

- Strongly prolate dark halo (halos are prolate in simulations: *Dubinski, Carlberg, 1991)*.

OR

- Long and thin filament at the galaxy center:



$$\Phi(r) = G\,\mu\,\ln\left(\frac{\sqrt{\ell_0^2 + r^2} + \ell_0}{\sqrt{\ell_0^2 + r^2} - \ell_0}\right),$$

Deformed Dark Profiles

- Commonly used density profiles: NFW and Burkert

$$\rho_{NFW} = \frac{\rho_0 r_0^3}{r(r+r_0)^2}\ ,\ \rho_B = \frac{\rho_0 r_0^3}{(r+r_0)(r^2+r_0^2)} \tag{1}$$

- Deformation $r^2 \to x^2 + y^2 + q^2 z^2$ with $q < 1$ results in steeper rises and shallower declines.

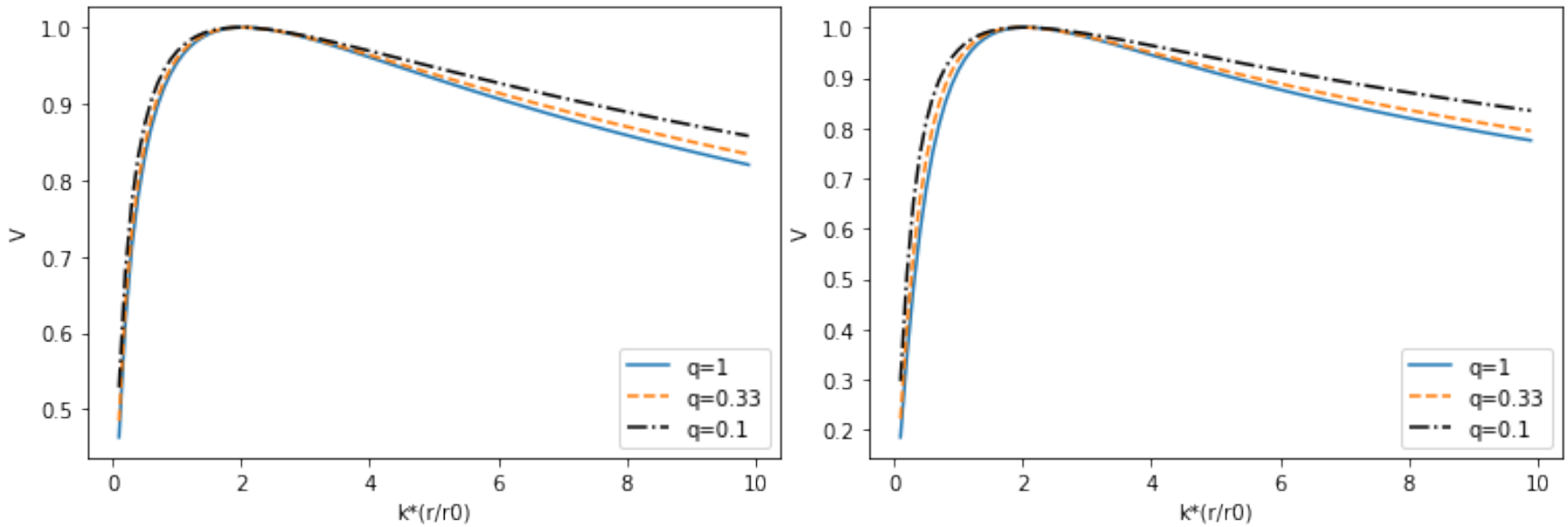


Figure 1: Rotation curve velocities, rescaled to have peak at 2 and normalized to unity (left: NFW, right: Burkert)

Galaxy fits

Fits of SPARC data (Lelli, McGaugh, Schombert, 2016) show that physically plausible deformations ($q >= 1/3$) yield only marginal improvement of order 6–7%.

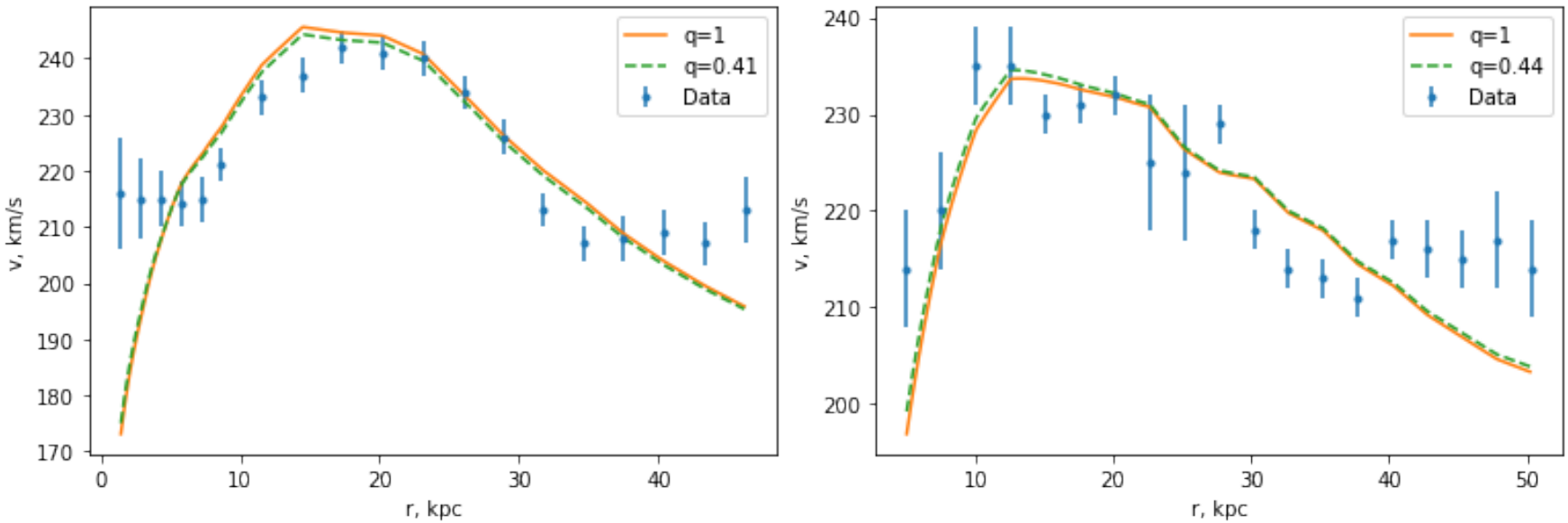


Figure 2: Rotation curve fits for galaxies NGC 5371 and NGC 5907 (NFW profile); the values around q=0.4 show only marginal improvement compared to q=1.

Galaxy fits

But: if we instead consider a string–like filament at the center, the improvement can be considerable! (40–70%)

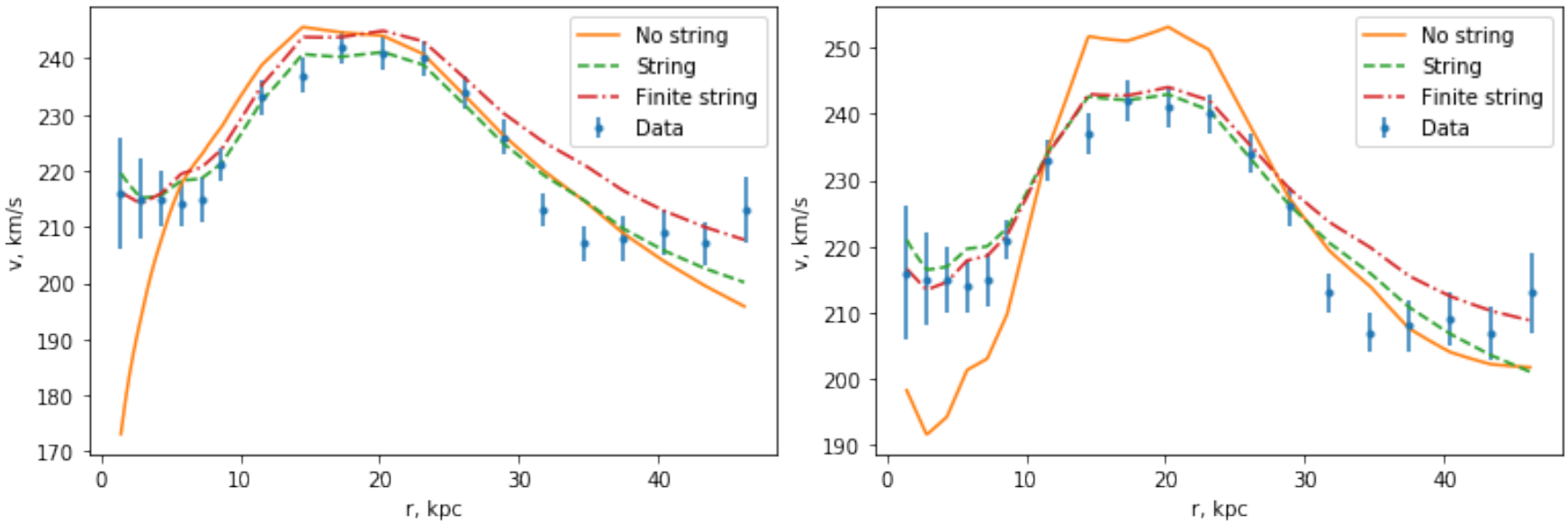


Figure 3: Rotation curve fits for galaxy NGC 5371; addition of a string–type filament yields considerable improvement for both NFW (left) and Burkert (right)

Galaxy fits

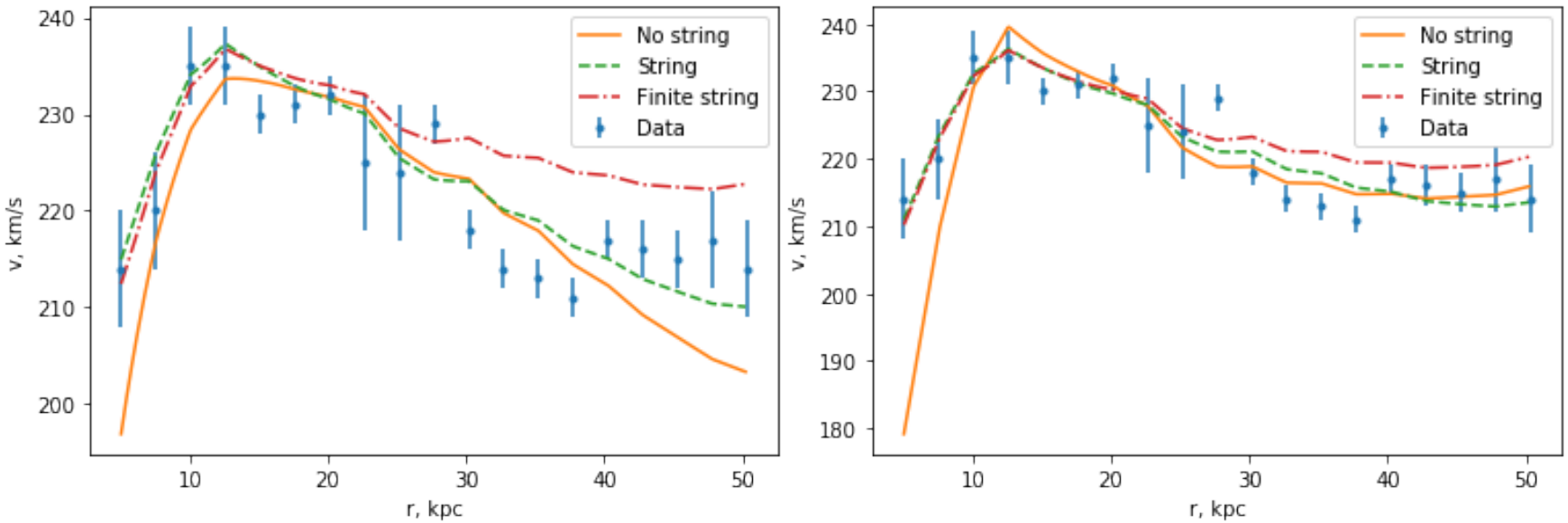


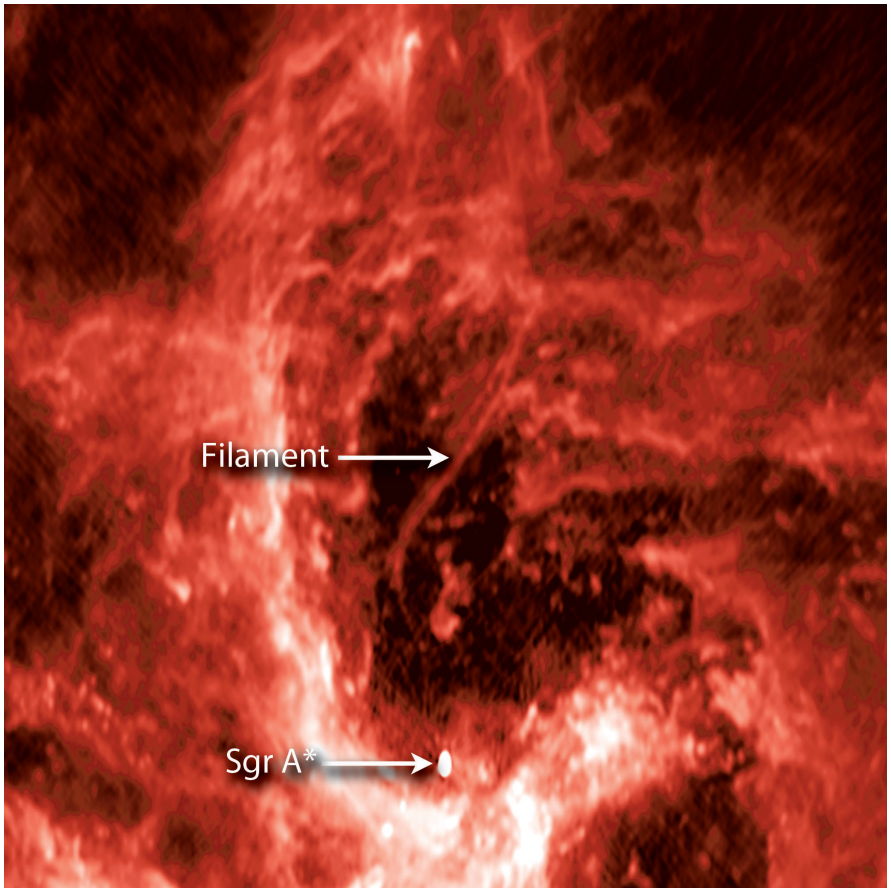
Figure 4: Rotation curve fits for galaxy NGC 5907; addition of a string–type filament yields considerable improvement for both NFW (left) and Burkert (right)

What could these objects be?

- Tidal streams? NGC 5907 (“knife-edge galaxy“) has an extended stucture of this type
- Black–hole jets or spaghettified objects? (baryonic and/or dark matter)
- Any relation to the intergalactic filaments?

Cosmic strings?

- *Morris, Zhao, Goss (2017)*: mysterious radio filament at the center of Milky Way (see also: *F. Yusef-Zadeh*);
- *Chudnovsky, Field, Spergel, Vilenkin, 1986; Vilenkin, Levin, Gruzinov, 2018*: strings can migrate to galaxy center;
- NANOGRAV: GWs from cosmic strings? *(Blazi, Brdar, Schmitz, 2020; Ellis, Lewicki, 2021)*
- Filament tensions in our fits below the upper bound from Planck ($7.8 * 10^{-7}$)



Conclusions

- Considerable evidence for string–like filaments in about 5-15 galaxies from the 82 we analyzed.
- Dark halo shape does not appear to have a significant effect.
- Performing the same analysis for different profiles proves to be a powerful method for making model–independent conclusions about whether or not a certain feature is present.
- Gravitational lensing observations from EUCLID will tell us more about halo shapes and other structures.

Thanks for your attention!