Dark matter, stationarity, Newtonian dynamics

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Introduction

- Self-graviting systems: galaxies, stars, planets...
- Focus on galaxies in this talk

Galaxies

- Large systems of gas and stars held together by gravity
- Constantly evolving collisionless systems
- Relaxation times are much larger than the age of the Universe

Hierarchical growth

Galaxy merger

Normal galaxy

Gas inflows

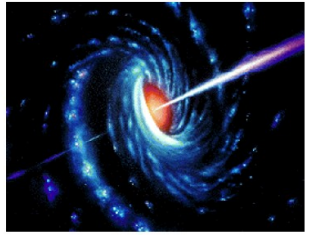
Galaxy formation and evolution

AGN feedback

Starbrust and AGN starting phase

Growth of BH

AGN - quasar

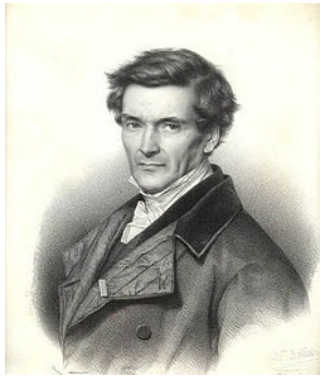


Starting equations

Material (Lagrangian) derivative

$\mathrm{d}/\mathrm{d}t$

Continuity equation



$$0 = \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}), \qquad (1)$$

Coriolis

Euler

$$\dot{\mathbf{v}} = -\nabla\Phi - \frac{\nabla \cdot \Pi}{\rho} - 2\boldsymbol{\Omega} \times \mathbf{v} - \mathbf{r} \times \dot{\boldsymbol{\Omega}} - \boldsymbol{\Omega} \times (\boldsymbol{\Omega} \times \mathbf{r}), \qquad (2)$$

Newton's equation of motion

$$\nabla^2 \Phi = 4\pi G \rho, \qquad (3)$$

centrifugal

Poisson's equation for gravitational potential

Starting equations

$$\frac{\dot{\rho}}{\rho} = \frac{\mathrm{d}}{\mathrm{dt}} \ln \rho = -\nabla \cdot \mathbf{v} \tag{4}$$

$$\nabla \cdot \left(\dot{\mathbf{v}} + 2\boldsymbol{\Omega} \times \mathbf{v} + \mathbf{r} \times \dot{\boldsymbol{\Omega}} + \boldsymbol{\Omega} \times (\boldsymbol{\Omega} \times \mathbf{r}) + \frac{\nabla P}{\rho} \right) = -4\pi G \rho. \tag{5}$$

$$\nabla \times \left(\dot{\mathbf{v}} + 2\boldsymbol{\Omega} \times \mathbf{v} + \mathbf{r} \times \dot{\boldsymbol{\Omega}} + \boldsymbol{\Omega} \times (\boldsymbol{\Omega} \times \mathbf{r}) + \frac{\nabla \cdot \Pi}{\rho} \right) = 0.$$

Final equation

- Fundamental equation of motion
- Kinematical equation! The evolution only depends on the initial and boundary setup.

$$\frac{\mathrm{d}}{\mathrm{dt}}\left(\ln\left(\nabla\cdot\left(\dot{\mathbf{v}}+2\boldsymbol{\Omega}\times\mathbf{v}+\mathbf{r}\times\dot{\boldsymbol{\Omega}}+\boldsymbol{\Omega}\times\left(\boldsymbol{\Omega}\times\mathbf{r}\right)+\frac{\nabla P}{\rho(P)}\right)\right)\right)+\nabla\cdot\mathbf{v}=0.$$

- Requires the knowledge of the initial acceleration

Dark matter

- Stationarity
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- Azimuthal symmetry
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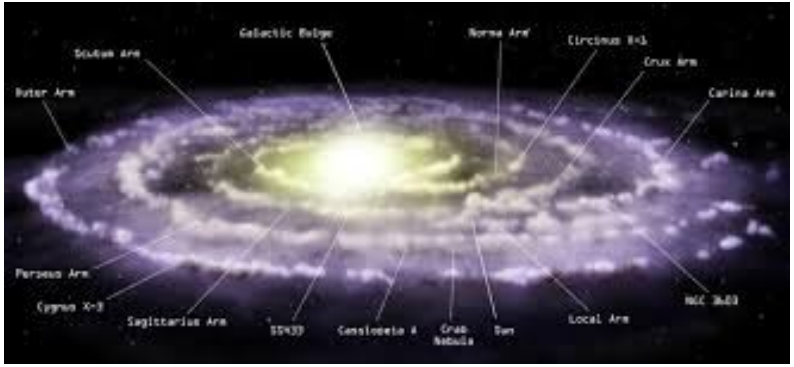
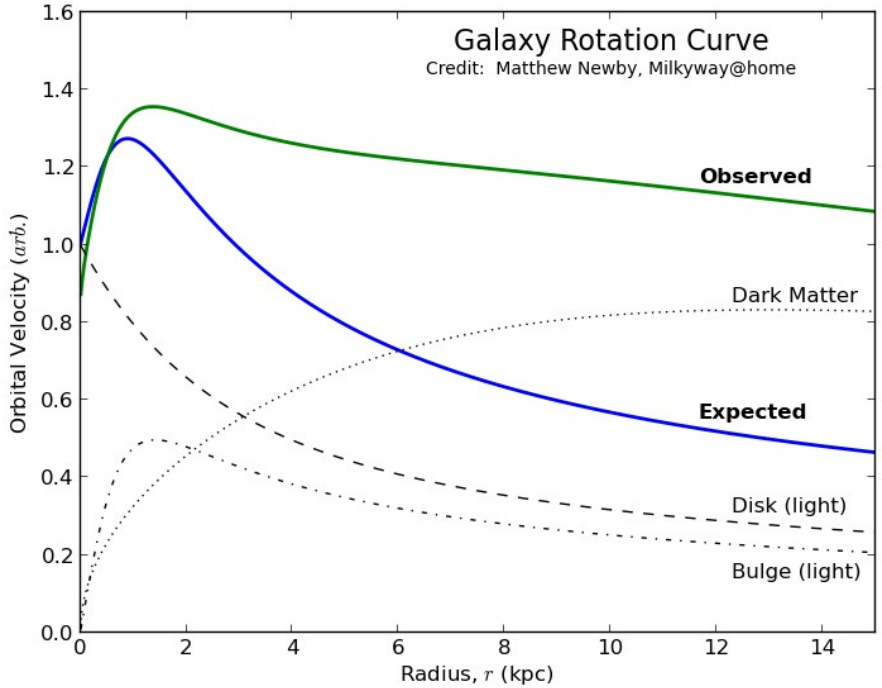
- Or correct equations?





Dark matter

- Simple solutions due to symmetry
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- Looks like we need more mass?
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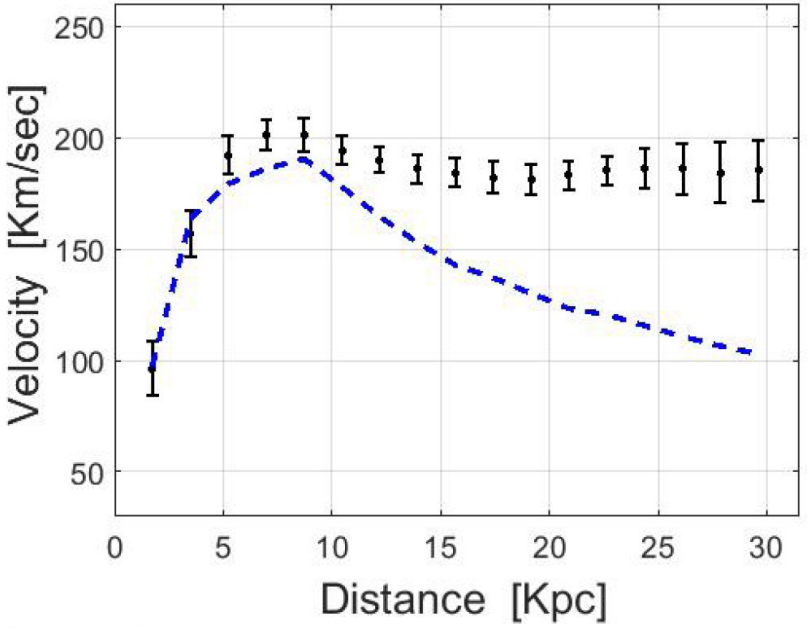
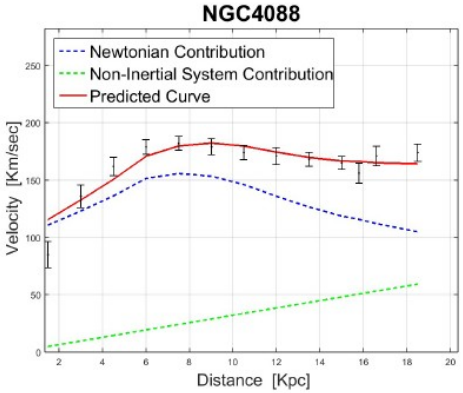
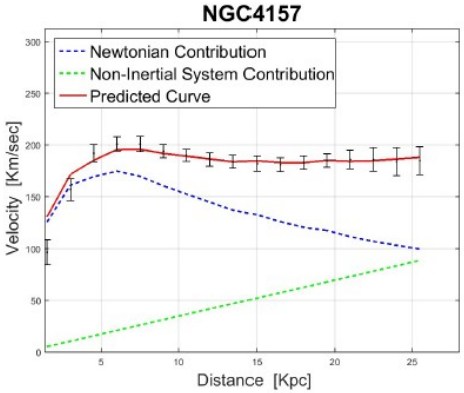
- Or correct equations?



Gomel & Zimmerman (2021)





Conclusions

- No possibilities of detecting dark matter via kinematics
- Lagrangian dynamics has no alternative for self-consistent description of galactic dynamics!!!