NCRA • TIFR

Mass models of gas-rich void dwarf galaxies

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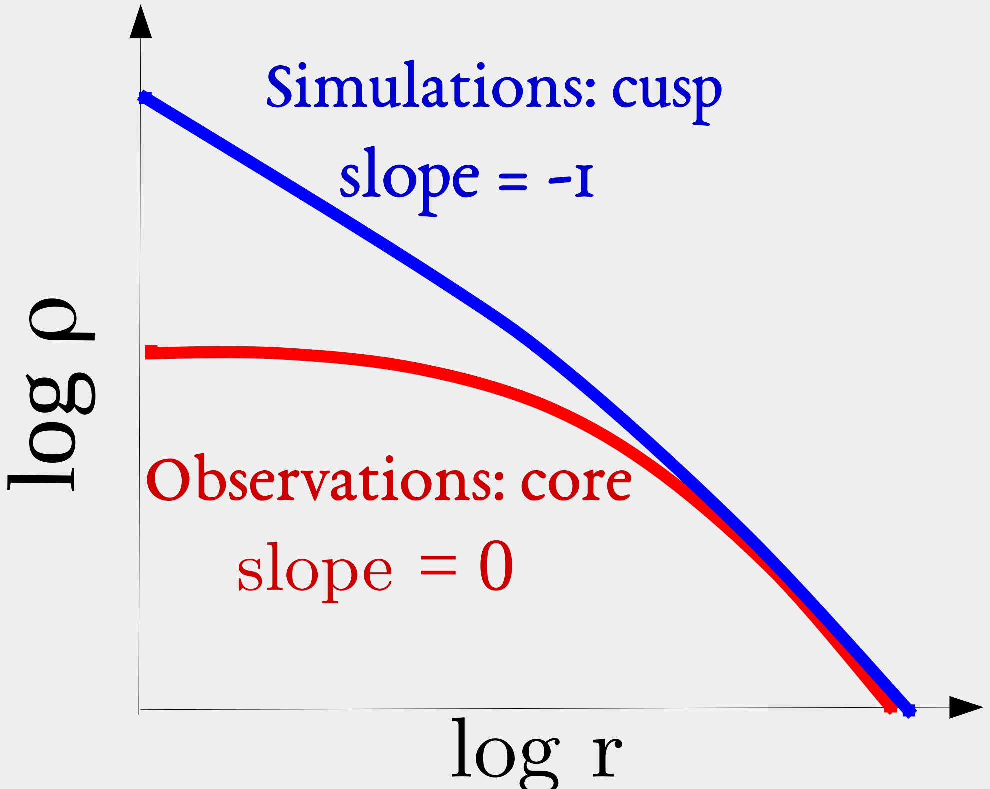
Plan of the talk

- Introduction: Cusp-core problem
  - Alternative dark matter (DM) models
  - Baryonic feedback
  - Systematics in rotation curves
- Tilted ring modelling: Rotation curves
  - 2D velocity fields
  - 3D data cubes
- Results
- Implications and Future work

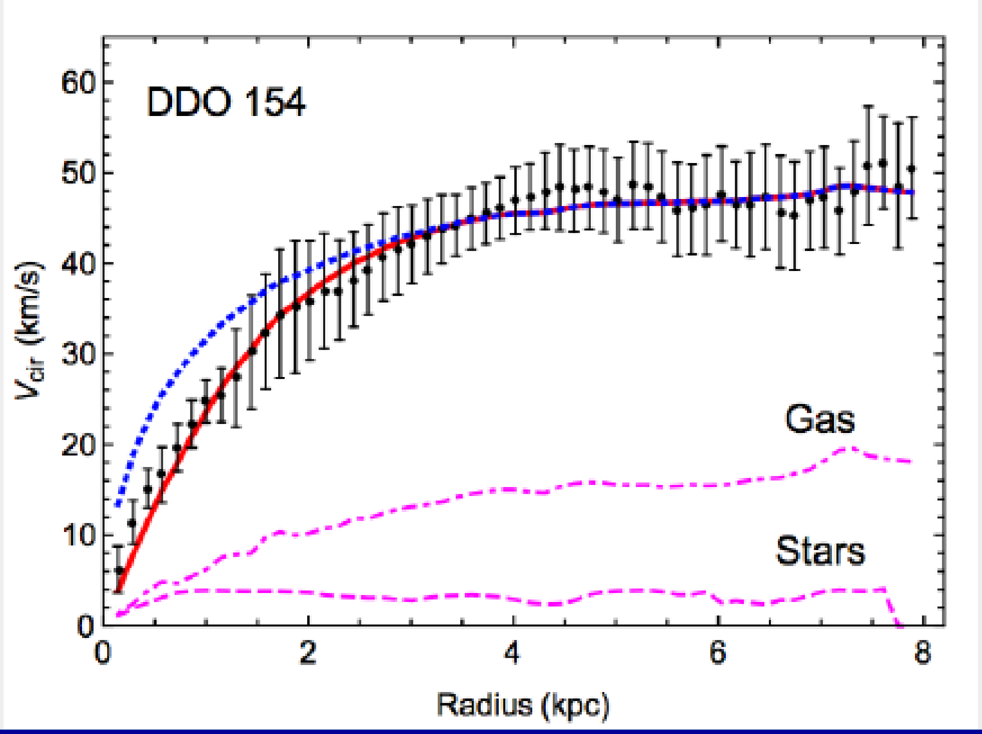
Introduction

- Λ Cold Dark Matter (ΛCDM) cosmology
  - successful on large scales (larger than ~10-100 kpc).
  - crisis on small scales: e.g. Cusp-core problem
- Cusp-core problem: Dwarfs prefer a shallow DM density core instead of a cusp



Cusp-core problem

- CDM simulations predict that central density of DM follows a power law $\rho \sim r^{\alpha}$
  - with slope $-0.8 < \alpha < -1.5$ *(e.g. Di Cintio et al. 2014)*
  - for NFW halo: $\alpha = -1$ (*Navarro et al. 1996*)
- However, observations give $\alpha \sim -0.2$, which is consistent with Isothermal (ISO) halo ($\alpha \sim 0$).



Cusp-core problem

- Lead to various solutions
  - DM models could be more complex than current models.
    (e.g. Schneider et al. 2017)
  - Including baryonic feedback processes have generated cores in some simulations. *(e.g.Pontzen & Governato 2012)*
  - Systematics in rotation curves.
    (e.g.Oman et al. 2017; Pineda et al. 2017)

Systematic effects

- Residual systematics in modelling Rotation Curves (RCs)
  - Smoothing of RC because of the finite resolution.
  - Incorrectly measured inclination angles. (*e.g. Read et al. 2016b)*
  - Improperly modelled pressure support. *(e.g. Pineda et al. 2017)*
  - Unmodelled non-circular motions. *(e.g. Oman et al. 2017)*
- To investigate systematic effects, we use the rotation curves derived from both 3-D and 2-D approaches for mass models.

Sample

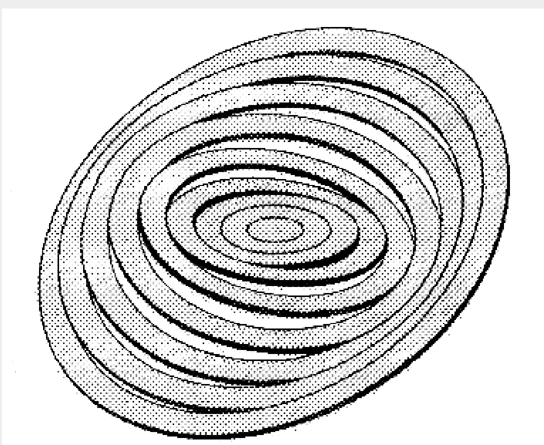
- Gas-rich dwarf galaxies were selected from Lynx-Cancer void

  (Pustilnik et al. 2011)

- To get good rotation curves, galaxies with
  - well behaved velocity fields
  - at least 6 beams across the major axis
  - inclinations greater than 35^0 were selected.
- This gives a sample of 8 galaxies.

Rotation curves

- Tilted ring model was fit to
  - HI data cube using Fully Automated TIRRIFIC (FAT; Kamphuis et al. 2015)
  - Velocity field using 'Rotcur' in GIPSY



(Rogstad et al. 1974)

Rotation curves

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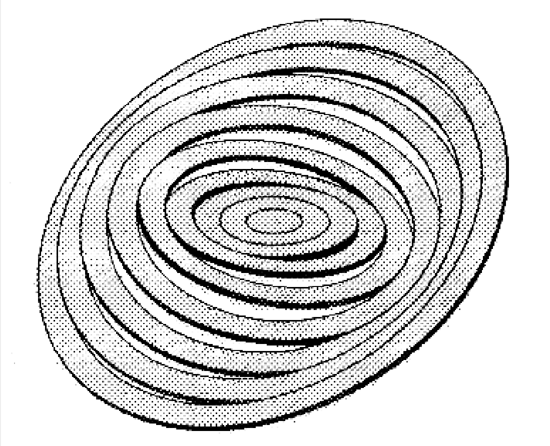
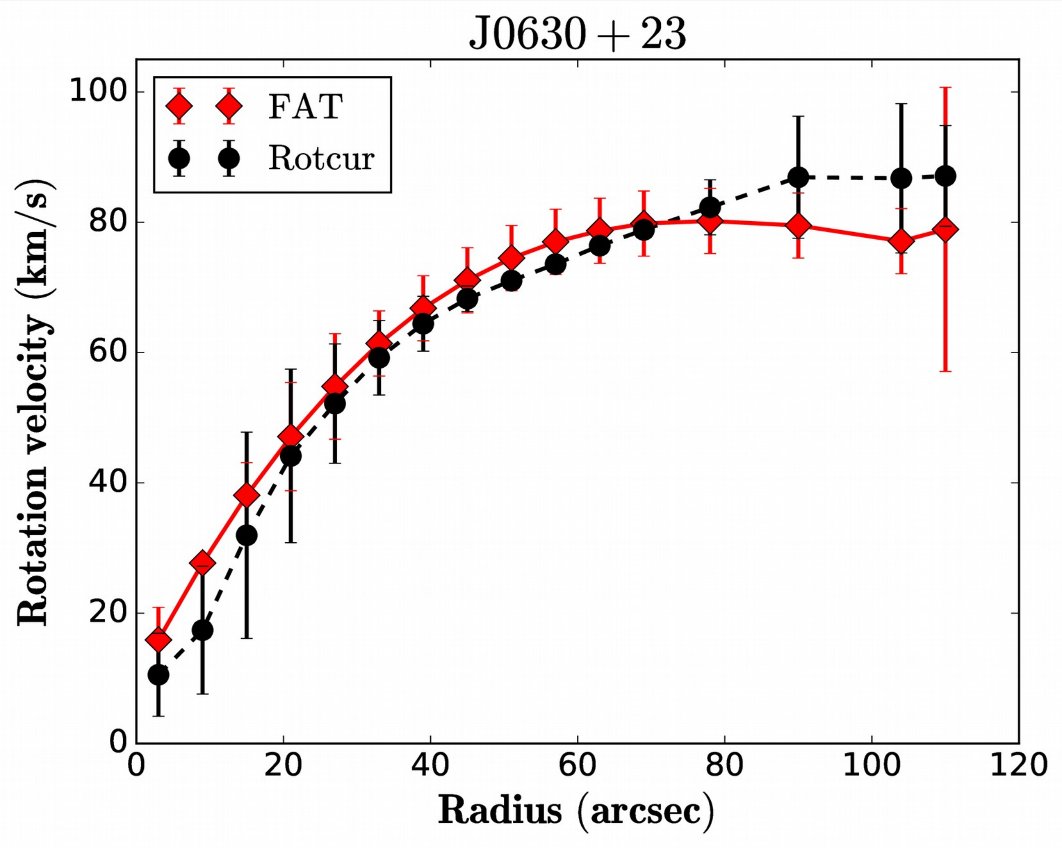
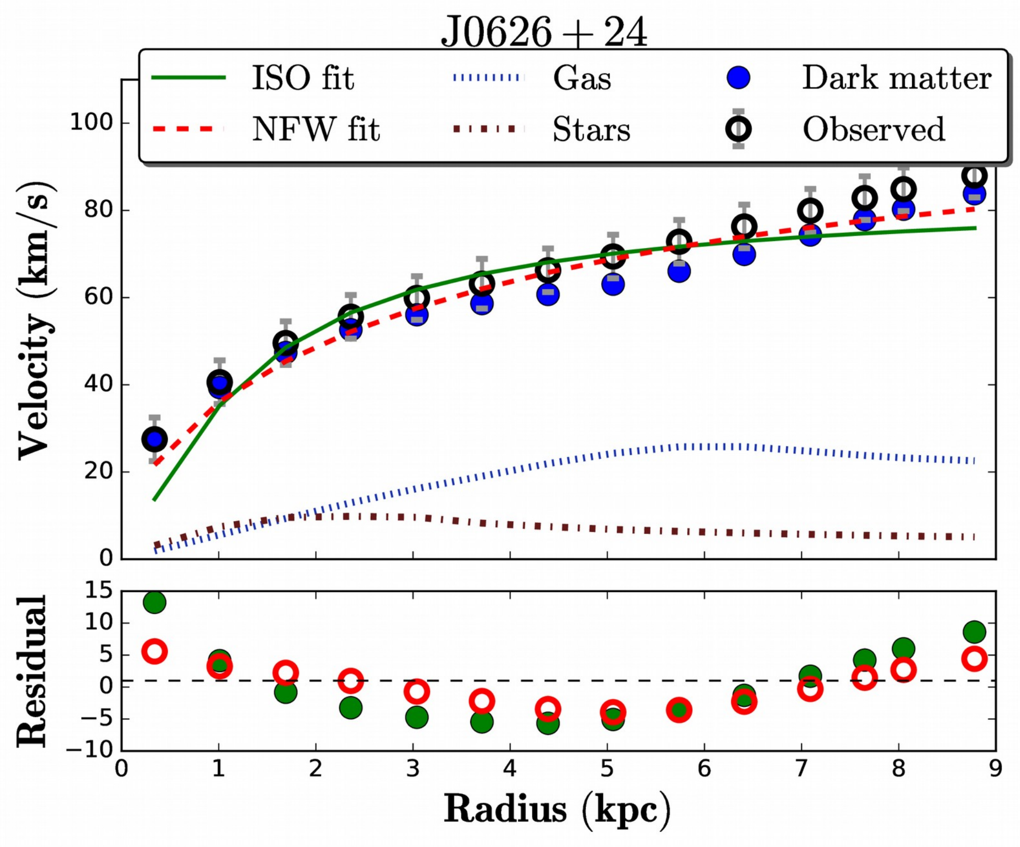
Kurapati et al. 2018a

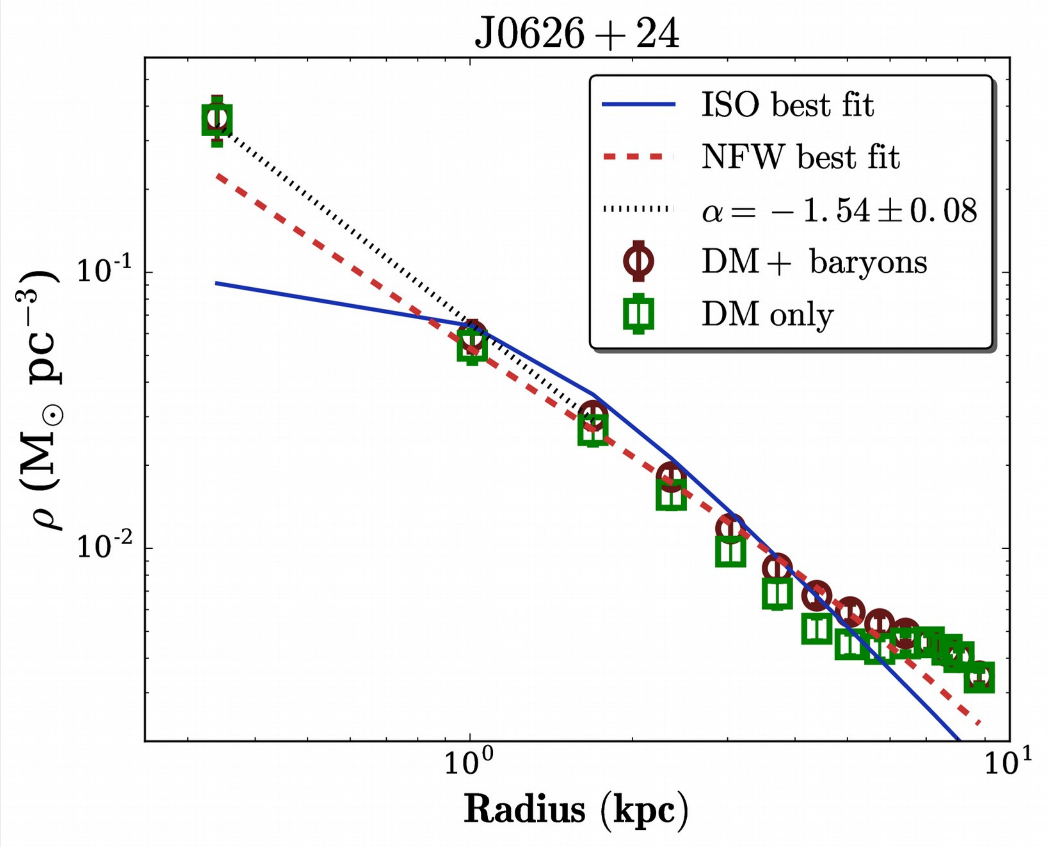


(Rogstad et al. 1974)



Mass modeling: 3D approach



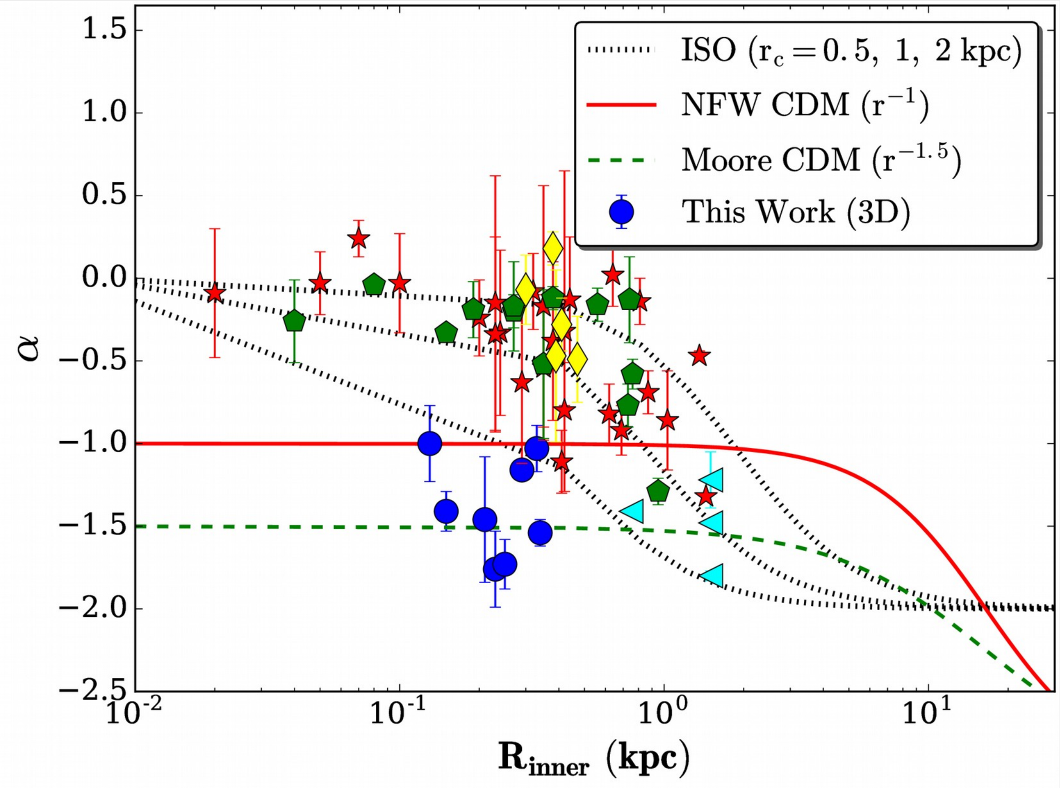


Kurapati et al. 2019, submitted

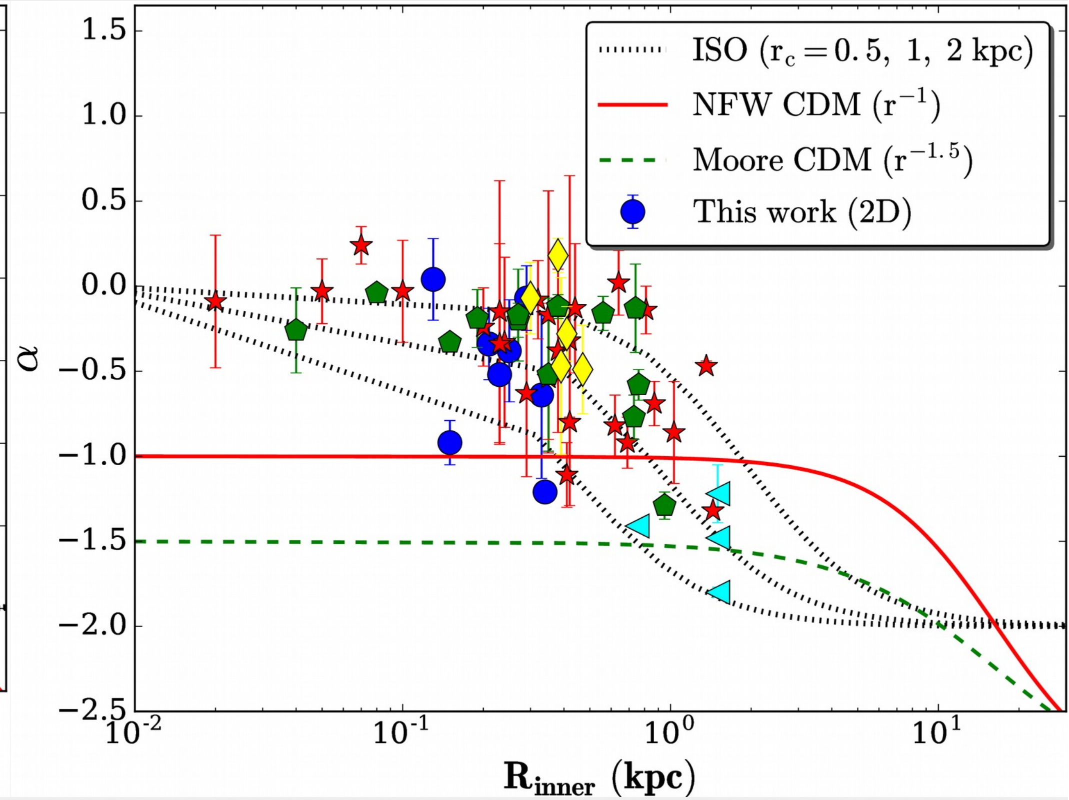
DM profile is consistent with NFW halo in central regions.

DM inner slope - resolution

Density from 3-D approach



Density from 2-D approach



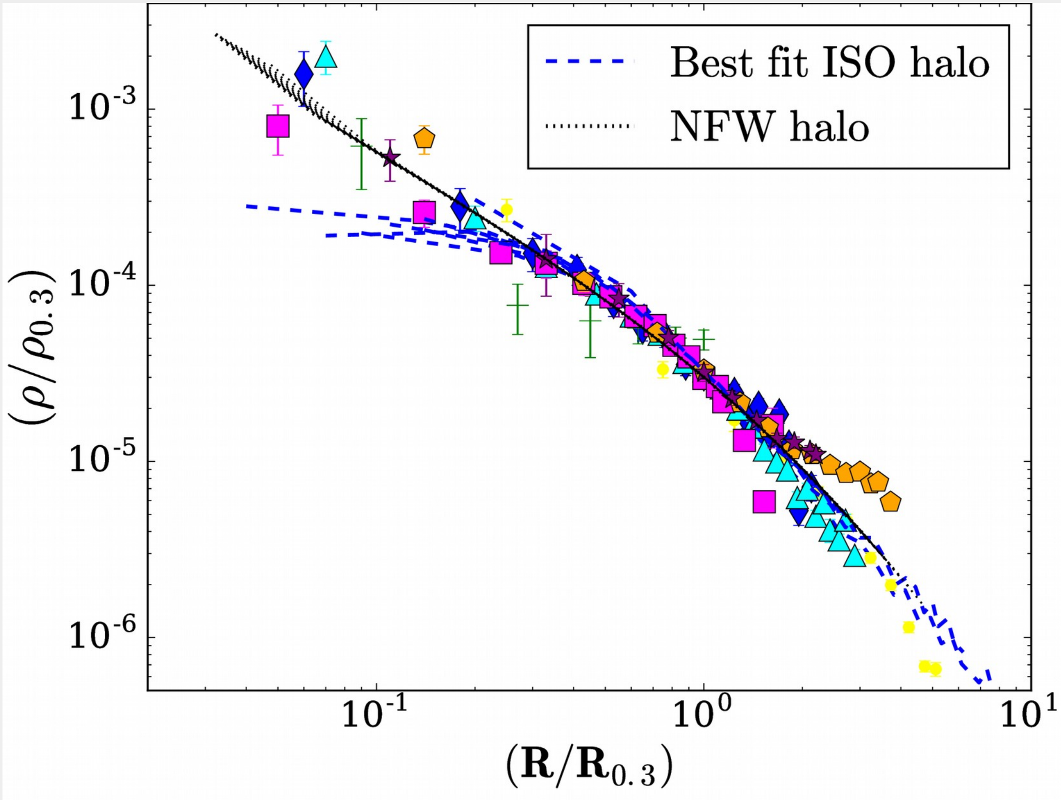
Kurapati et al. 2019, submitted

3D approach: average α (-1.39±0.19) is steeper than literature.

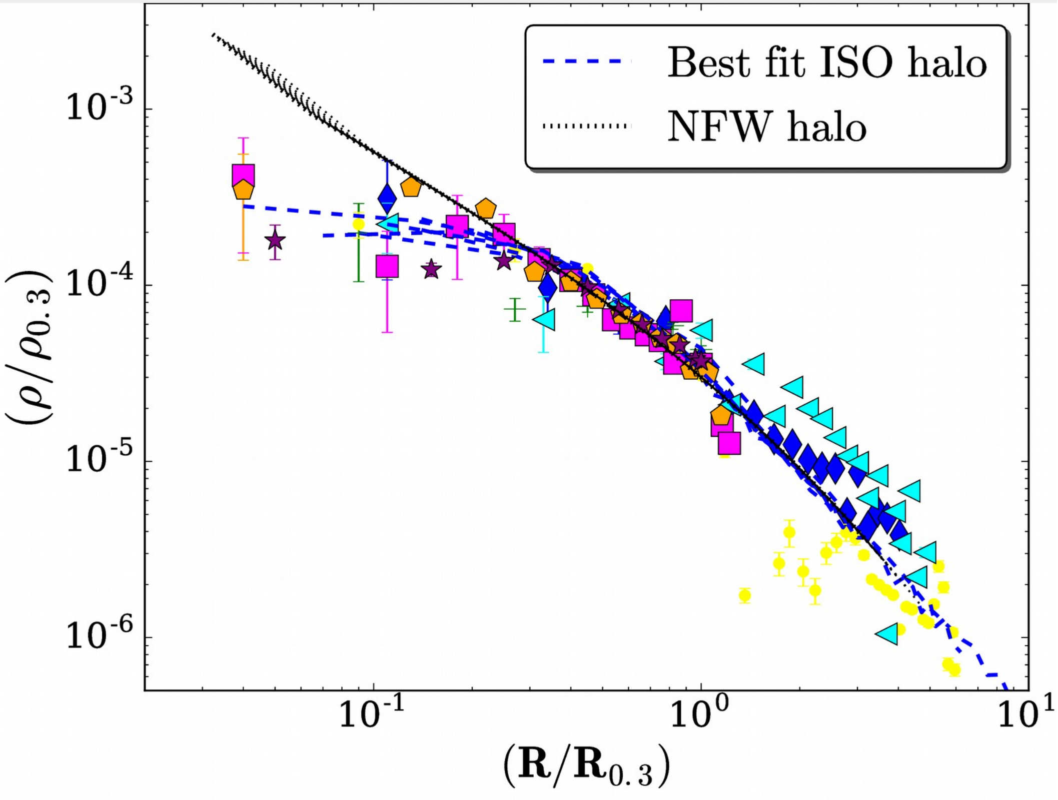
2D approach: average α (-0.49±0.24) matches with literature.

DM density profiles

Density from 3-D approach



Density from 2-D approach



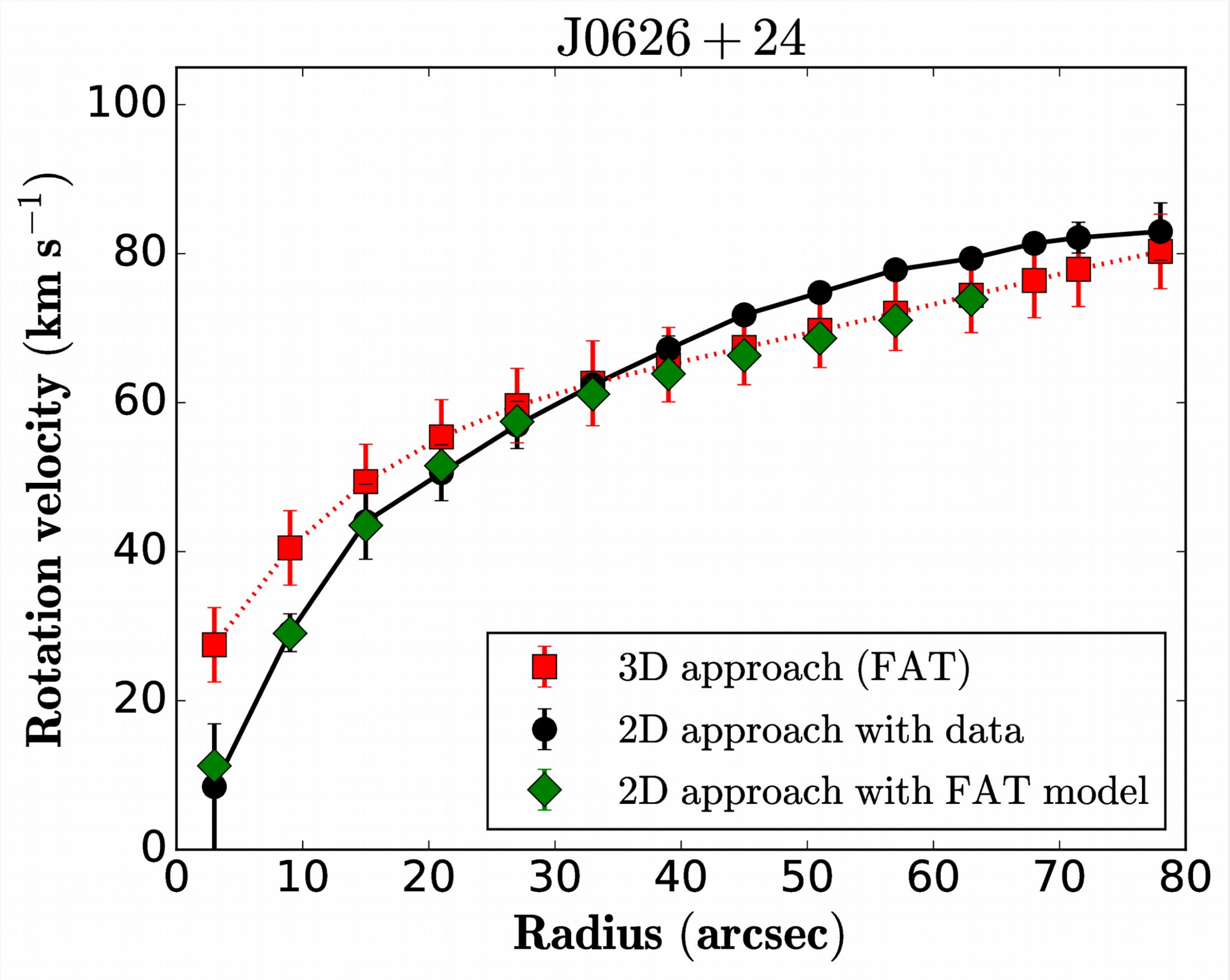
Kurapati et al. 2019, submitted

DM profile from 3-D approach matches with NFW halo.

DM profile from 2-D approach matches with ISO halo.

Systematics: 2-D approach

Kurapati et al. 2019, submitted



RC derived with FAT 3D model matches closely with the data.

Summary

- Rotation curves of 8 dwarfs were derived using 2-D & 3-D tilted ring fitting routines.
- Average slope (α = -1.39±0.19) obtained from 3-D fitting is consistent with NFW profile
- Average slope (α = -0.49±0.24) obtained from 2-D fitting is closer to isothermal profile.
- Fundamental differences in 3-D and 2-D routines may affect slope of central DM density profiles.

Additional slides

Dark matter density profiles

- Isothermal (ISO) halo:
  - constant density cores, $\alpha = 0$ in central regions.
  - $\rho(r)=\rho_0/[1+(r/r_c)^2]$,
  - ρ_0 is central density, r_c is core radius are free parameters.
- NFW halo: (Navarro et al. 1997)
  - cusped density cores, $\alpha = -1$ in central regions.
  - $\rho_{NFW}(r)=\rho_i / [(r/r_s)(1+r/r_s)^2]$, r_s is characteristic radius, ρ_i is related to density of universe at the time of collapse.
  - r_{200} is radius at which density is 200 times critical density, concentration parameter $c= r_{200} /r_s$ are free parameters.

DM halo parameters - environment