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ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

SURFS March 2013

A Novel Approach To Quantifying Dark Matter Halo Structure

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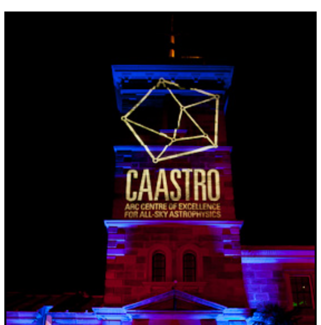

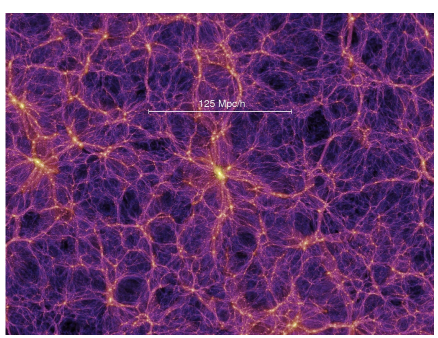

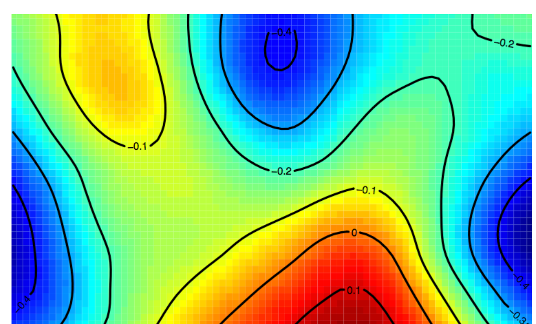

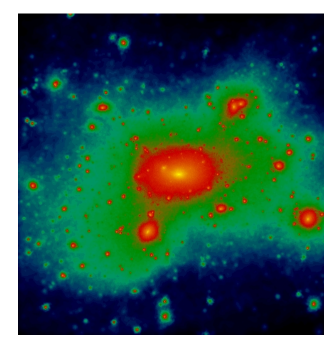

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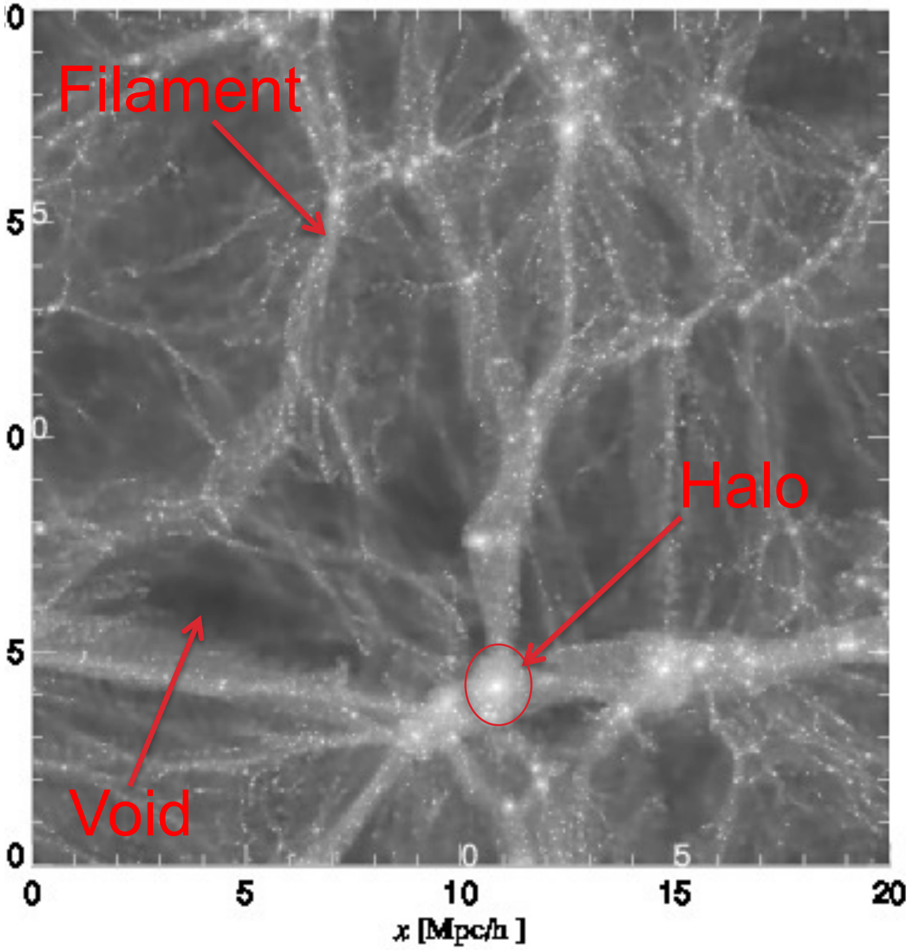
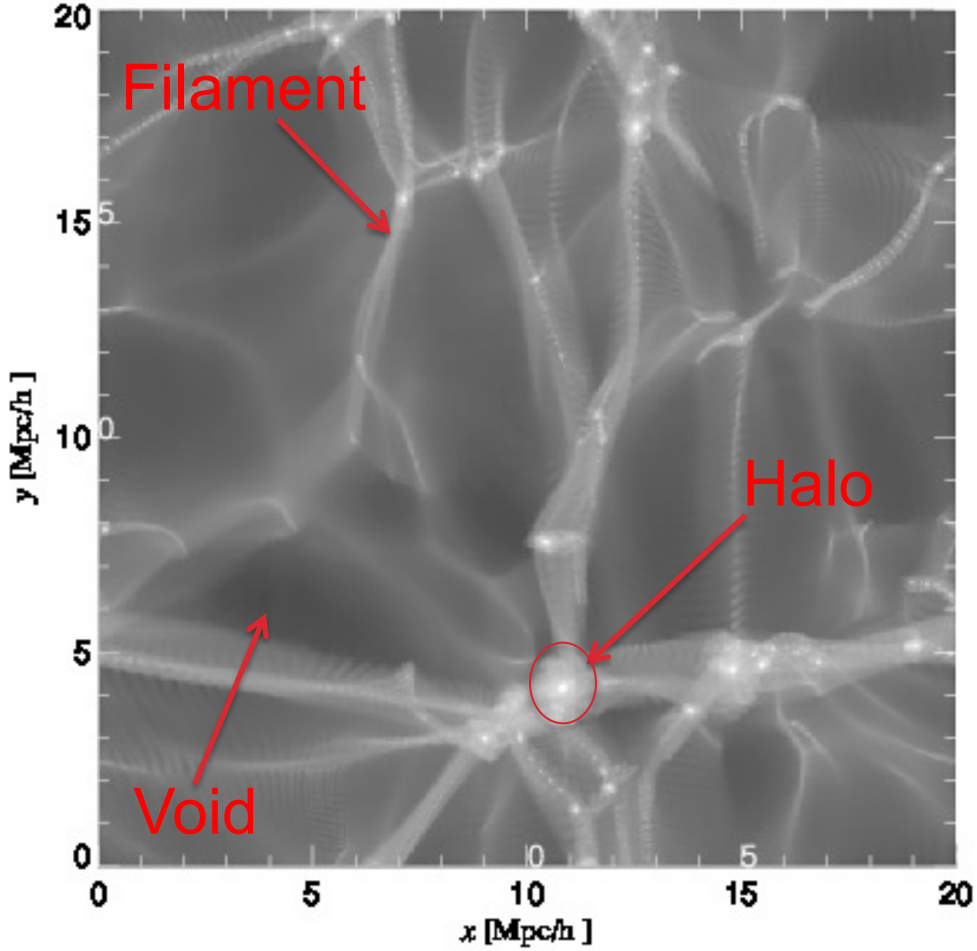
Motivation: Dark Matter

CDM



WDM



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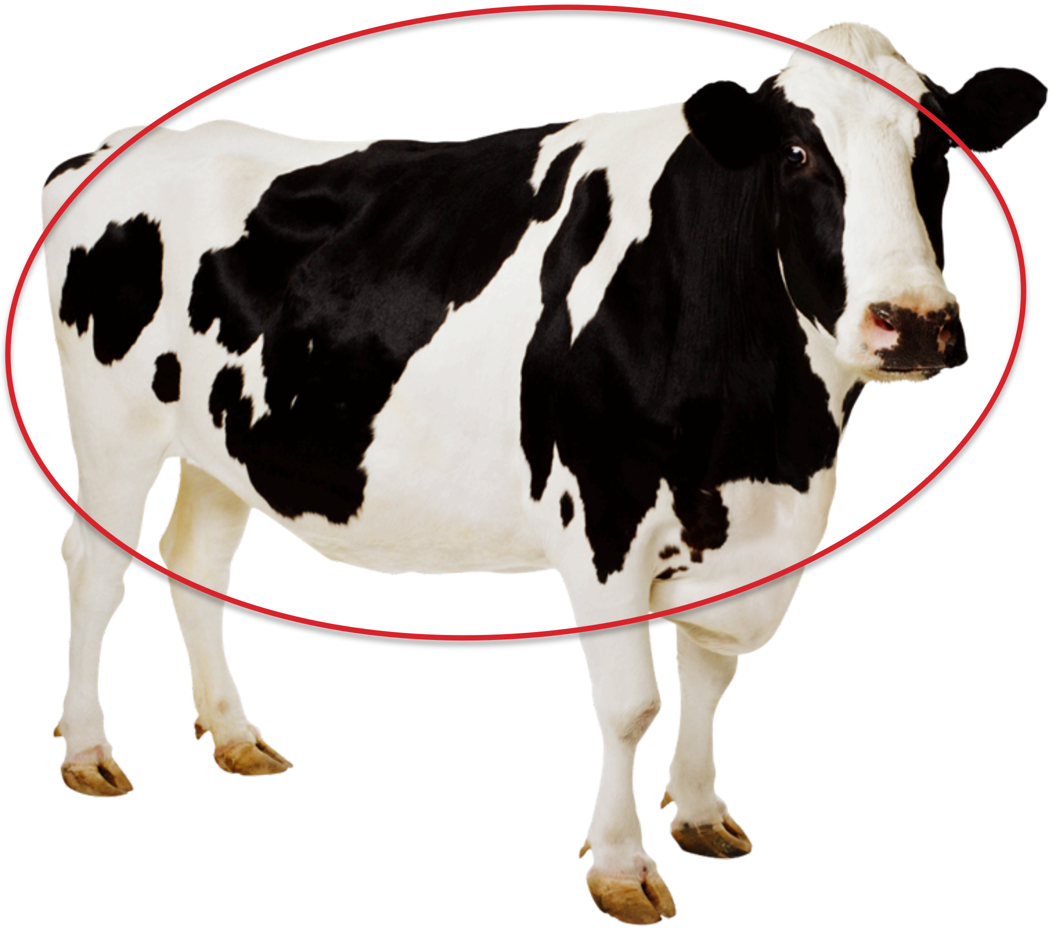
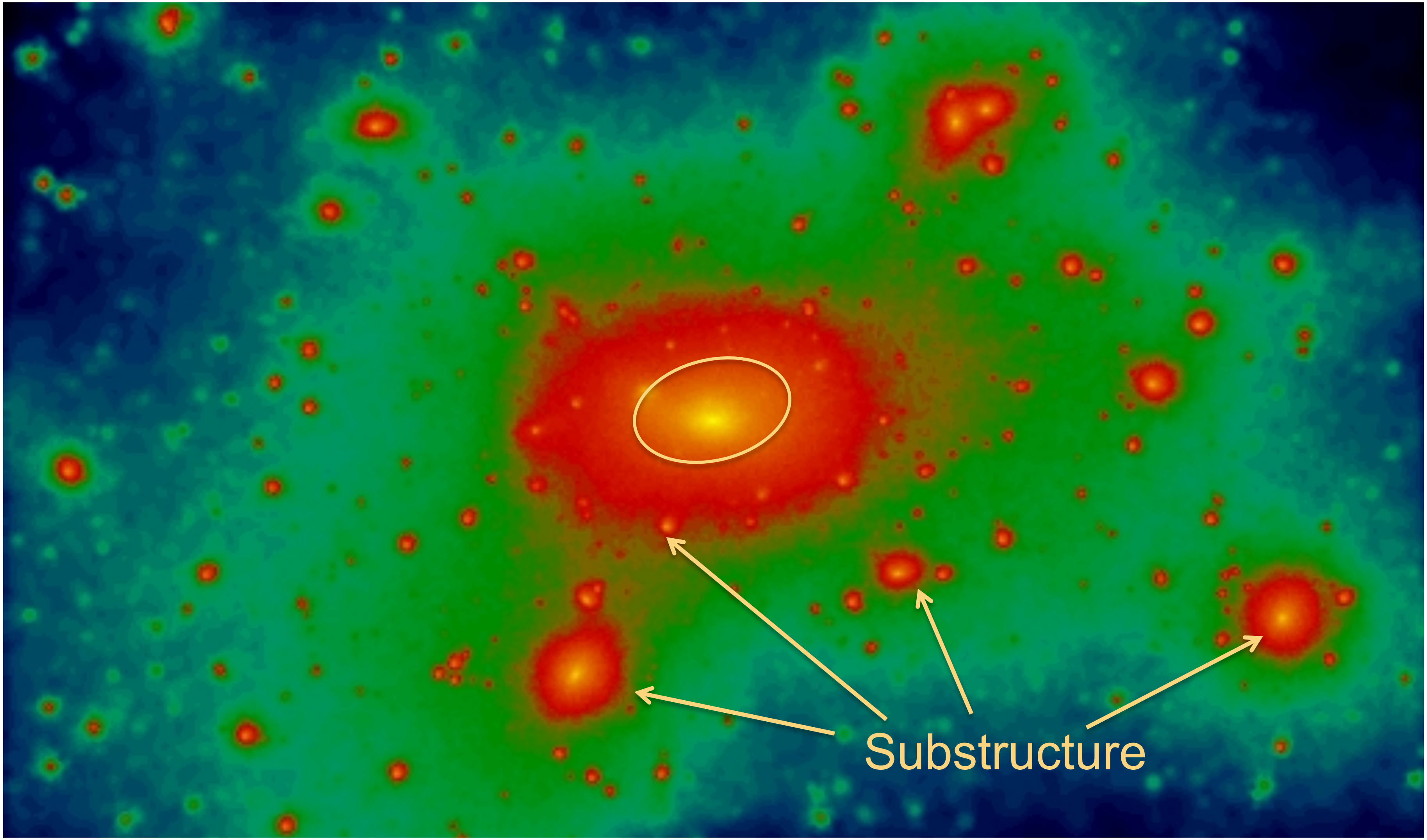
Bovine Philosophy

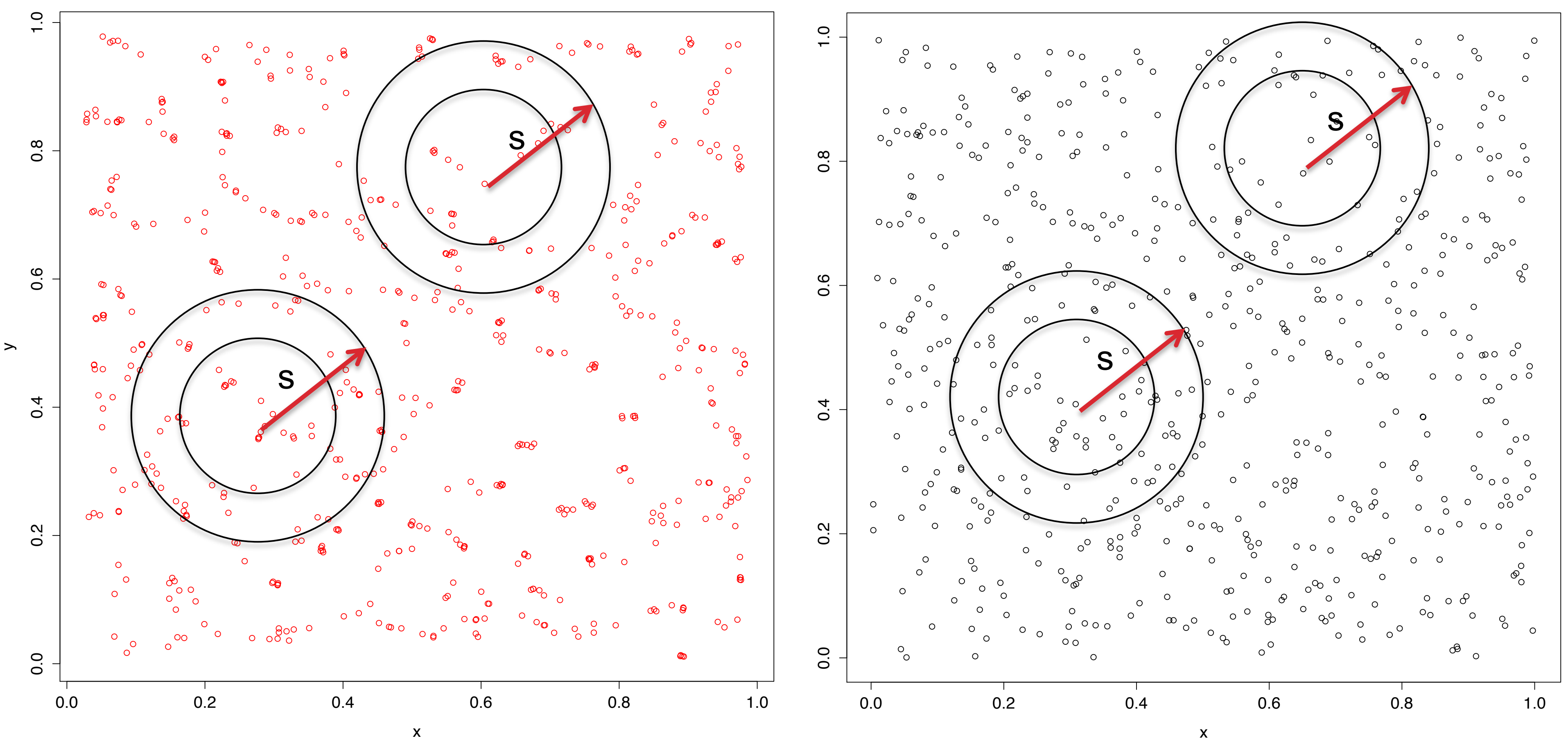


ELLIPTICITY = 0.7

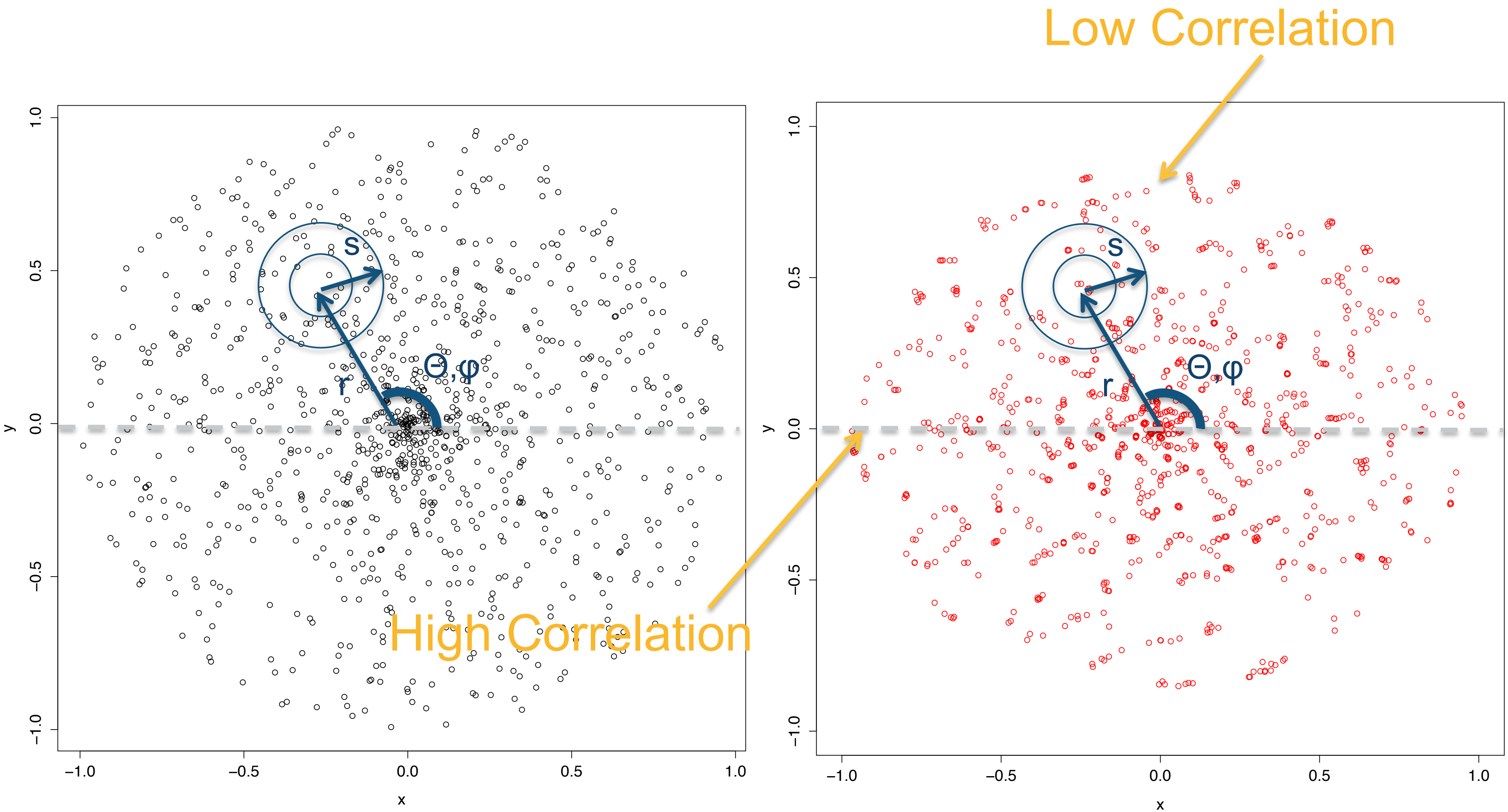
Dark Matter Halo Properties



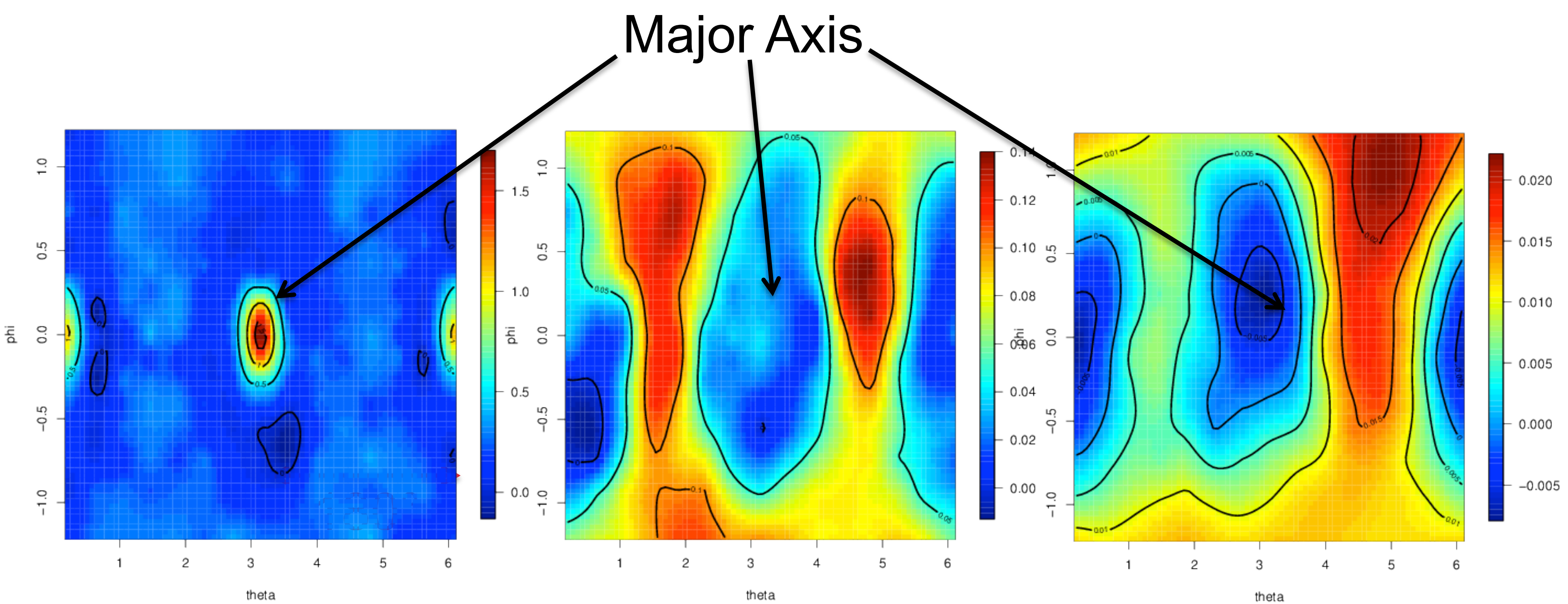
The Correlation Function

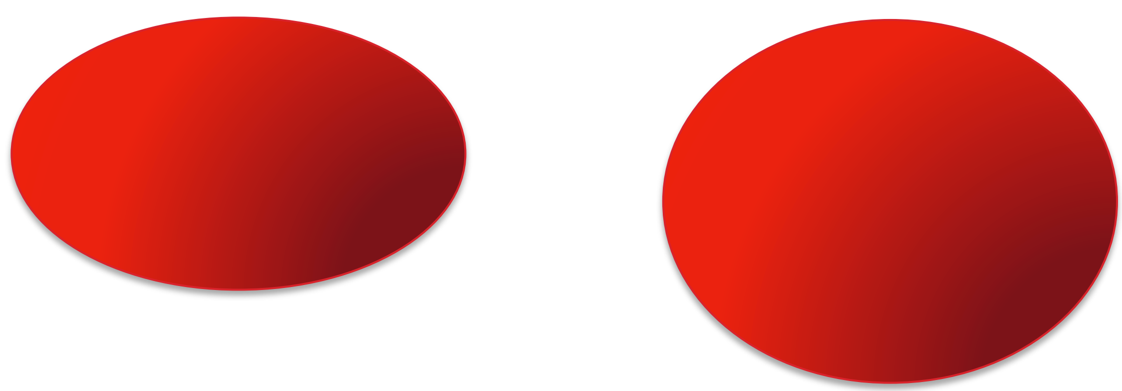


In Real Life…


Low Correlation
High Correlation
S
r
Θ,φ
S
r
Θ,φ
1.0
0.5
0.0
−0.5
−1.0
y
x
−1.0
−0.5
0.0
0.5
1.0

Shapes of Ideal Haloes

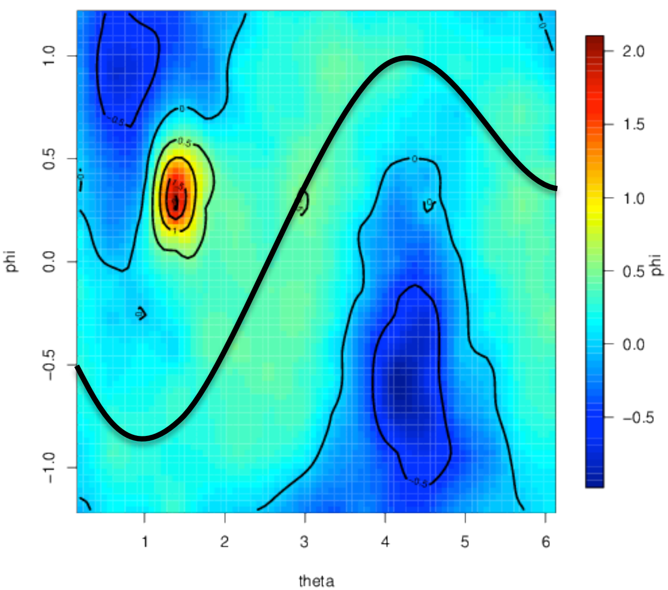




Prolate [cigar-like]

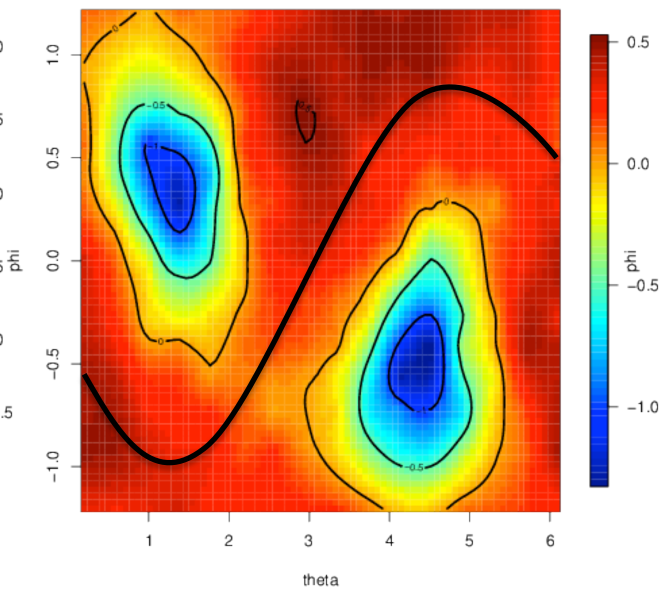
Shapes of Simulated Haloes

T = 0.94



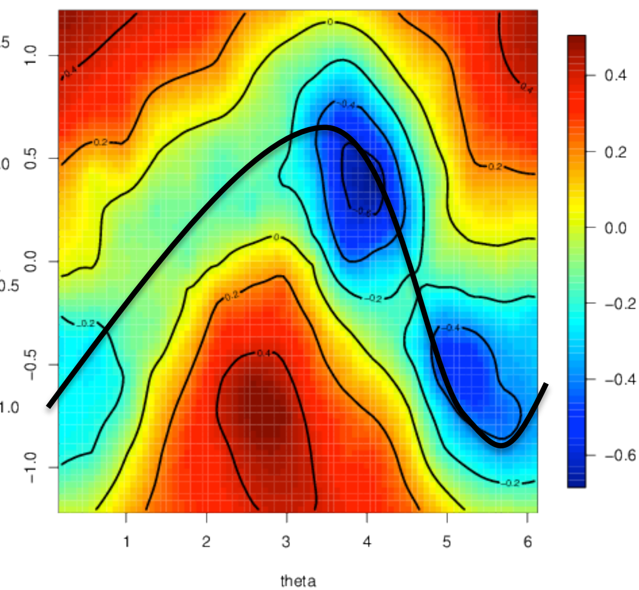
Prolate [Cigar-like]

T = 0.76



Triaxial [in-between]

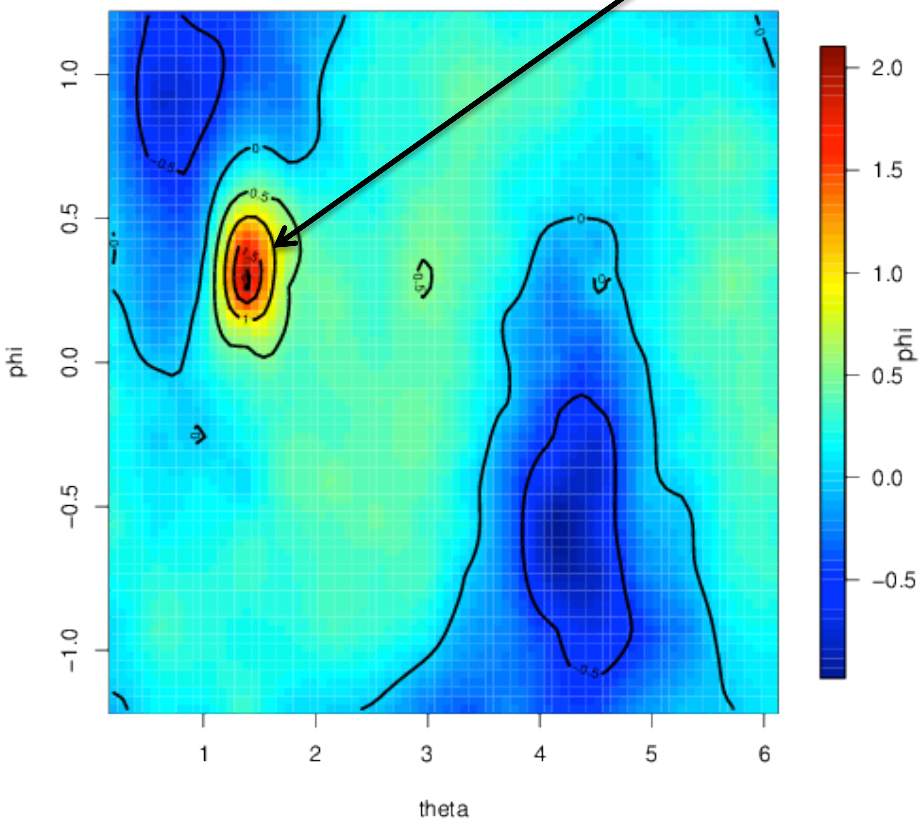
T = 0.25



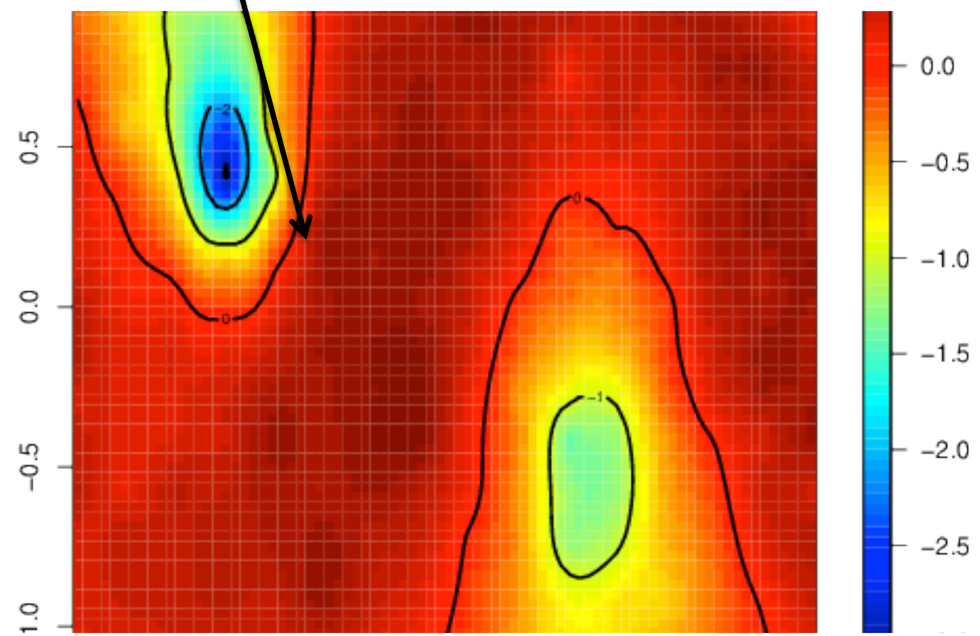
Oblate [disk-like]

The Effect of Scale

Substructure …. Gone



$s = \{0,0.3\}*R_{vir}$



$s = \{0.3,0.5\}*R_{vir}$

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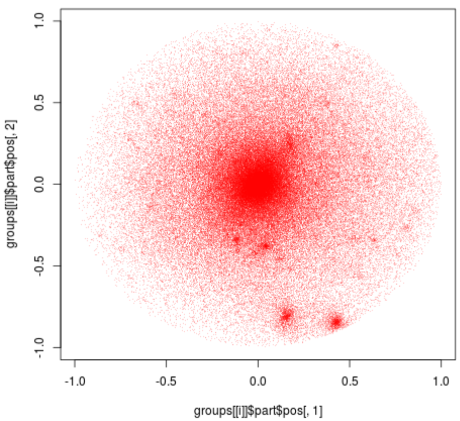
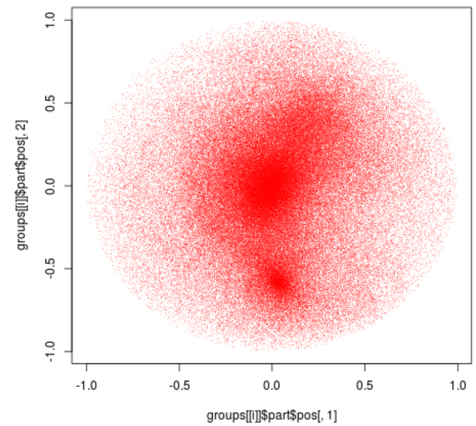
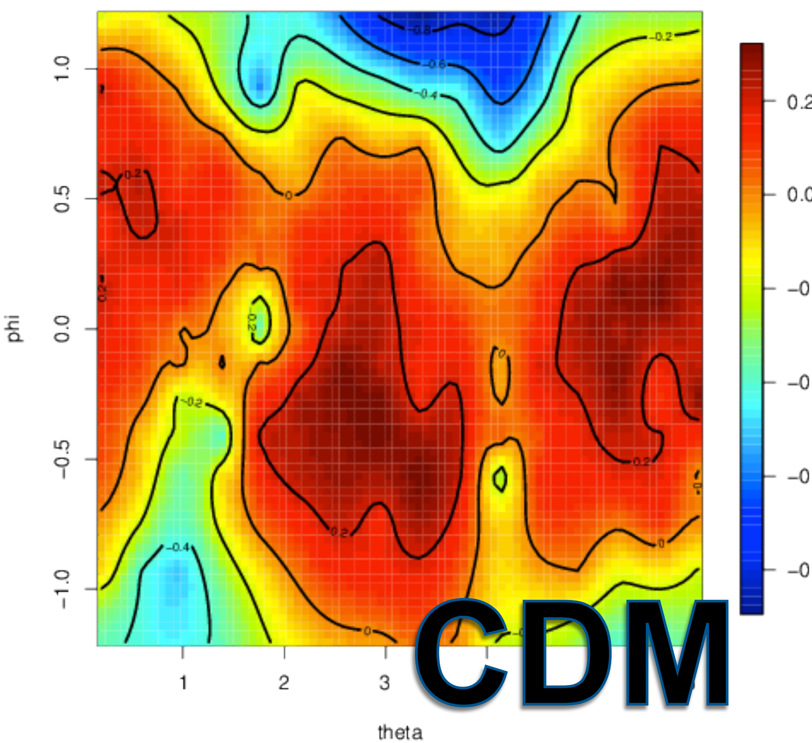
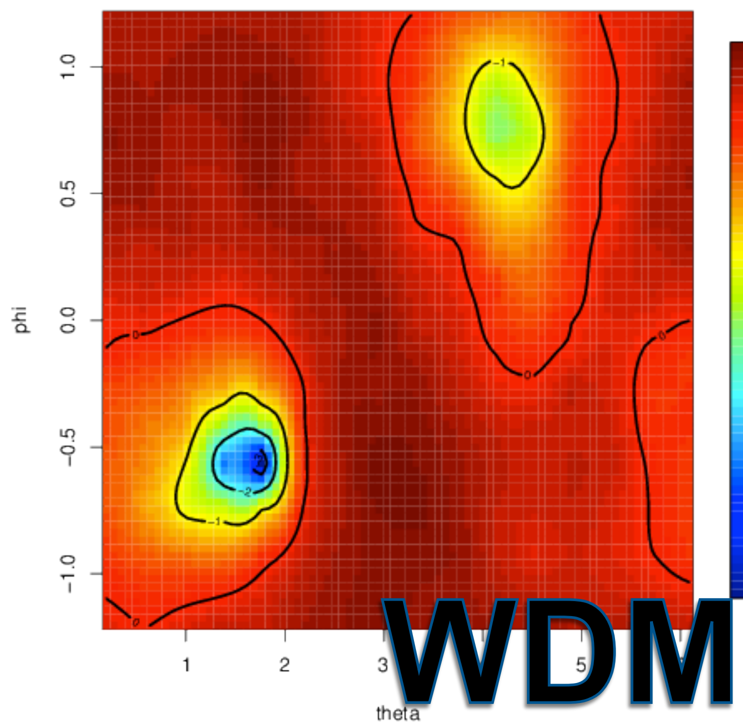
CDM vs WDM









Summary & Intentions

- Traditional shape measurements of haloes very **simplistic**
- New method developed which **doesn't assume ellipsoidal form**
- Based on the 2-point correlation function
- **May be useful for testing the nature of dark matter**

- We will extend the method to other properties using other co-ordinates (eg. substructure)
- Include more information (eg. velocities)
- Compare results across dark matter models.

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HMF WEB-APP

- Website: hmf.icrar.org

- My email (please send me bugs, design flaws, features you want to see):
  steven.murray@uwa.edu.au

Extra Notes I: Generalizing…

- Start with

$$\xi(\vec{s}) = \int f(\vec{x}) f(\vec{x}+\vec{s})\, d\vec{x}$$

- Convert to spherical polar:

$$\xi(s) = \int\int\int\int\int f(r,\theta,\varphi) f(\hat{r},\hat{\theta},\hat{\varphi}) r^2 \cos\varphi \cos\varphi_s \, dr\, d\theta\, d\varphi d\theta_s d\varphi_s$$

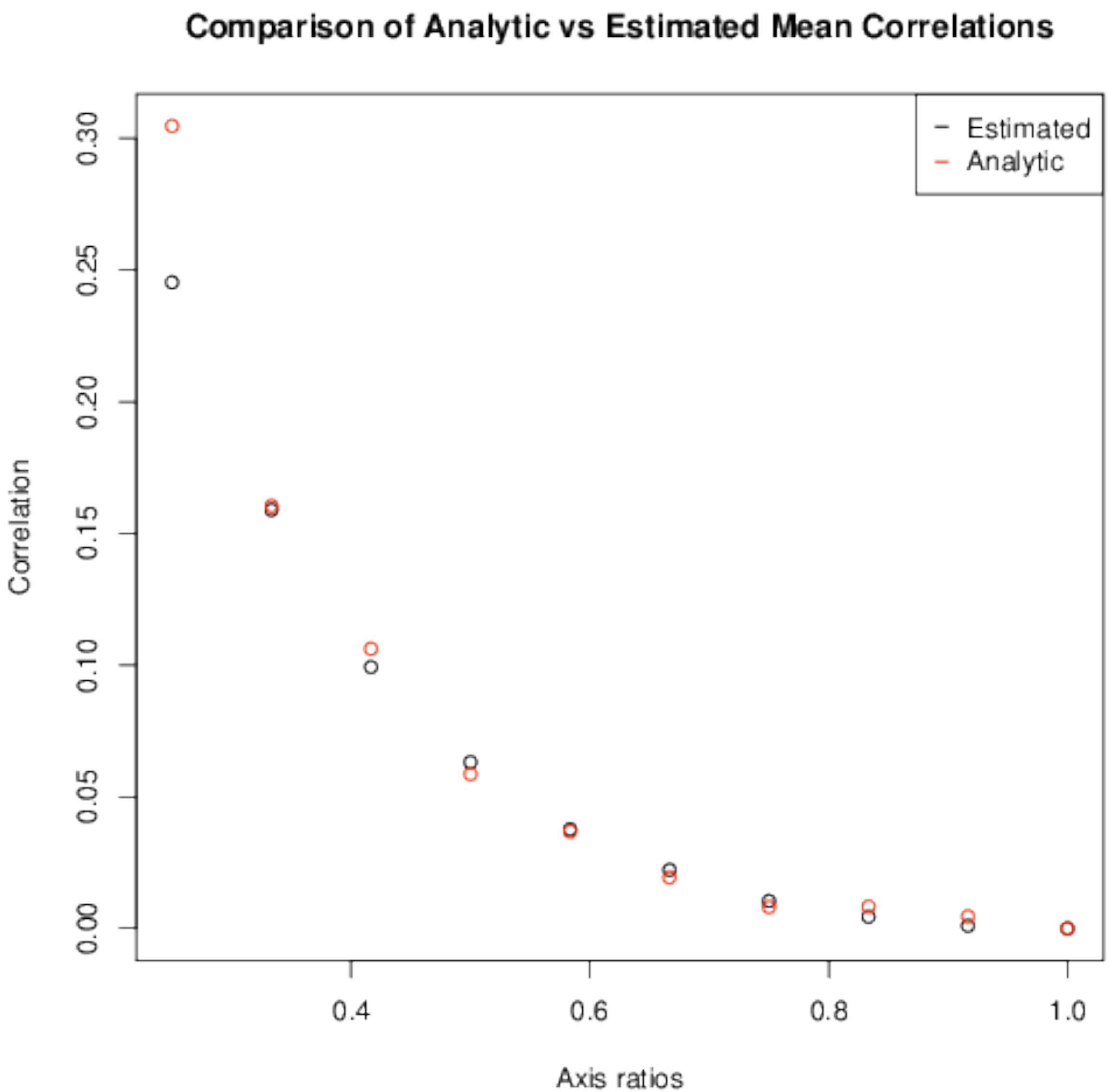
- What about using other co-ordinates in the correlation? Or none at all?
- Mean Correlation:

$$\bar{\xi} = \underbrace{\int\int\int\int\int\int}_{\text{All 6 Co-ords}} f(r,\theta,\varphi) f(\hat{r},\hat{\theta},\hat{\varphi}) r^2 \cos\varphi s^2 \cos\varphi_s \underbrace{dr\, d\theta\, d\varphi\, d\theta_s\, d\varphi_s\, ds}_{\text{All 6 Co-ords}}$$

- Correlation of angular co-ords:

$$\xi(\theta,\varphi) = \underbrace{\int\int\int\int}_{\text{4 Co-ords}} f(r,\theta,\varphi) f(\hat{r},\hat{\theta},\hat{\varphi}) r^2 s^2 \cos\varphi_s \underbrace{dr\, ds\, d\theta_s\, d\varphi_s}_{\text{4 Co-ords}}$$

Extra II: Proof That It Works



Extra III: Scale Effect