Evidence for dark matter self-interactions in Abell 3827?

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PASCOS 2015

02/07/2015

Based on arXiv: 1504.06576, MNRAS Letters (accepted for publication)

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DESY

Outline

- Motivation
- Evidence in A 3827?
- Interpretation
  - Frequent Interactions
  - Rare Interactions

Motivation

> Problems of the ΛCDM-model on small scales:
  - Cusp-vs-core problem
  - Too-big-to-fail problem
  - Missing-satellite problem

> "Baryonic feedback" may solve these problems… or DM Self-interactions with

$$\sigma/m_{DM} \sim 1 \ \mathrm{cm}^2/\mathrm{g}$$

[Steinhardt, Spergel, 2000]

> Current bounds from e.g. Bullet Cluster

$$\sigma/m_{DM} \lesssim 1 \ \mathrm{cm}^2/\mathrm{g}$$

> Proposed test: galaxies falling into galaxy clusters

> The smoking gun signature for DM self-interactions would be an spatial offset between the (collisionless) stars and the DM halo of the infalling galaxy

Evidence in A 3827?

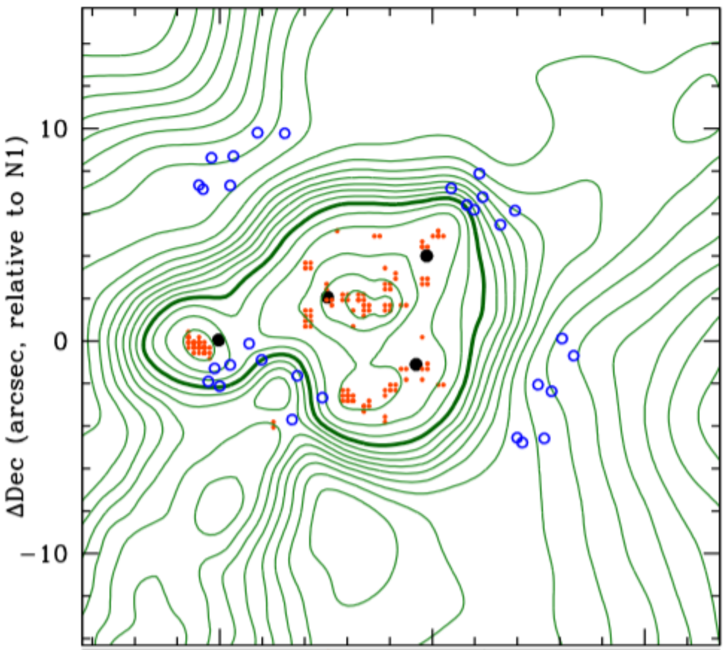
The behaviour of dark matter associated with 4 bright cluster galaxies in the 10kpc core of Abell 3827

[Massey et al., arXiv:1504.03388]

"The best-constrained offset is **1.62 ± 0.48 kpc**, where the 68% confidence limit includes both statistical error and systematic biases in mass modelling.

[…] With such a small physical separation, it is difficult to definitively rule out astrophysical effects operating exclusively in dense cluster core environments - but if interpreted solely as evidence for self-interacting dark matter, this offset implies a cross-section

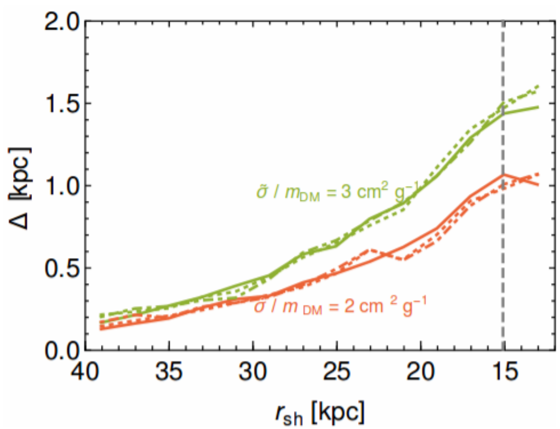
$\boldsymbol{\sigma/m = (1.7 \pm 0.7) \times 10^{-4}\ \mathrm{cm^2/g}\ (t/10^9\ \mathrm{yr})^{-2}}$, where t is the infall duration."

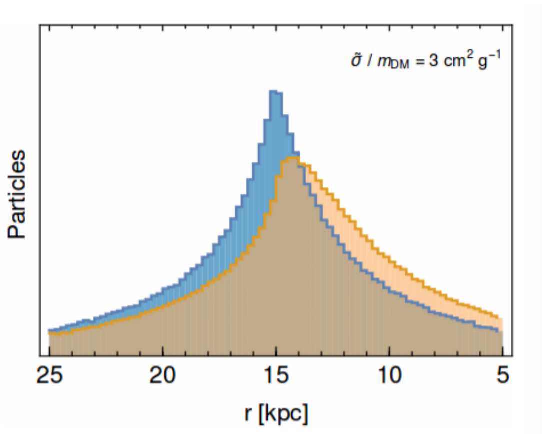


Robust measurement - but we do not find any dependence on the infall time, cross-section underestimated by factor of 10^4

Frequent Interactions

- Frequent self-interactions decelerate a DM halo, when moving through a background of DM particles
- This generates an effective drag force: $\frac{F_{\text{drag}}}{m_{\text{DM}}} = \frac{1}{4} \frac{\sigma_{\text{DM}}}{m_{\text{DM}}} \rho v^2$
- Full 3D simulation of frequent dark matter self-interactions

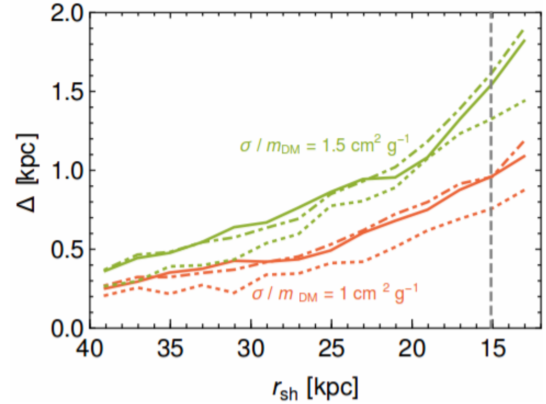


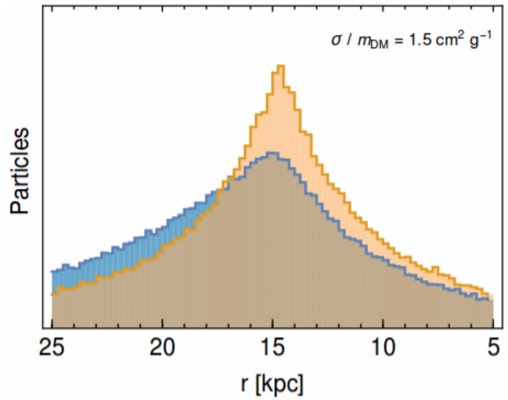


- $\sigma/\mathrm{m_{DM}} \sim 3\ \mathrm{cm^2/g}$
- DM distribution shifted in backwards direction
- Tail of stars in forward direction

Rare Interactions

- Interactions with large momentum transfer, like contact interactions
- Have to be rare, otherwise halo evaporates rapidly
- No effective drag force description possible
- Full 3D simulation of rare dark matter self-interactions





- $\sigma/\mathrm{m_{DM}} \sim 1.5\ \mathrm{cm}^2/\mathrm{g}$
- Peaks still coincide
- Tail of DM particles due to scattering in backwards direction

Conclusions

- Systems like A 3827 are good probes for DM self-interactions
- Cross-section of DM self-interactions is of expected order of magnitude for detection in other astrophysical systems
- Therefore this claim is falsifiable by other observations (in slight tension with existing bounds)
- Type of interaction (frequent or rare) in principle distinguishable