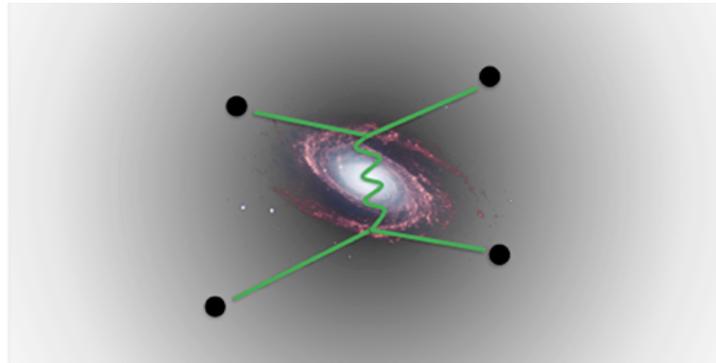


Dark Matter Halos as Particle Colliders

Hai-Bo Yu

University of California, Riverside

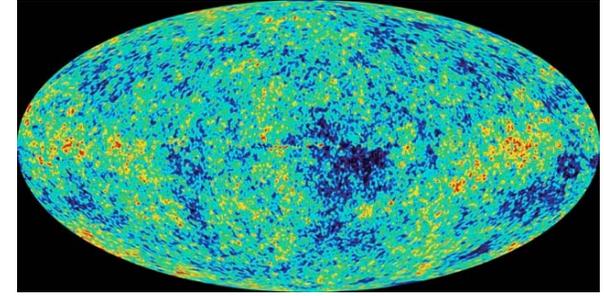
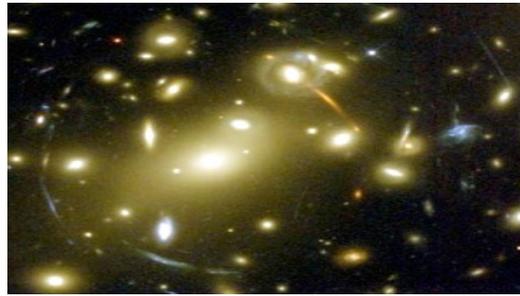
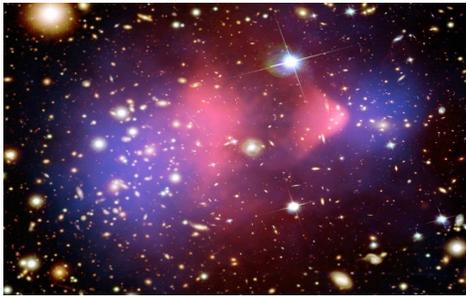


UCI Dark Matter, April 5, 2017

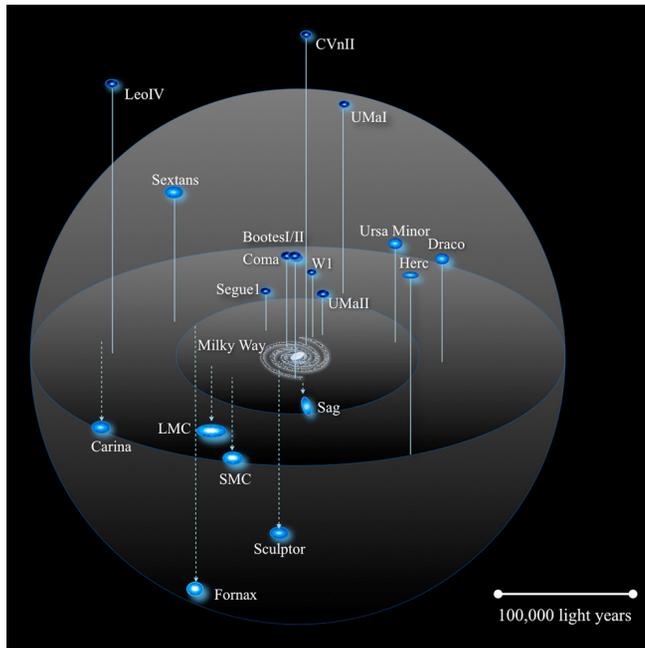
Review for Physics Reports: Sean Tulin, HBY arXiv: 1704.XXXXX

The CDM Model

- Large scales: very well



- Small scales (galaxies, subhalos, galaxy clusters): ?



Core vs. Cusp

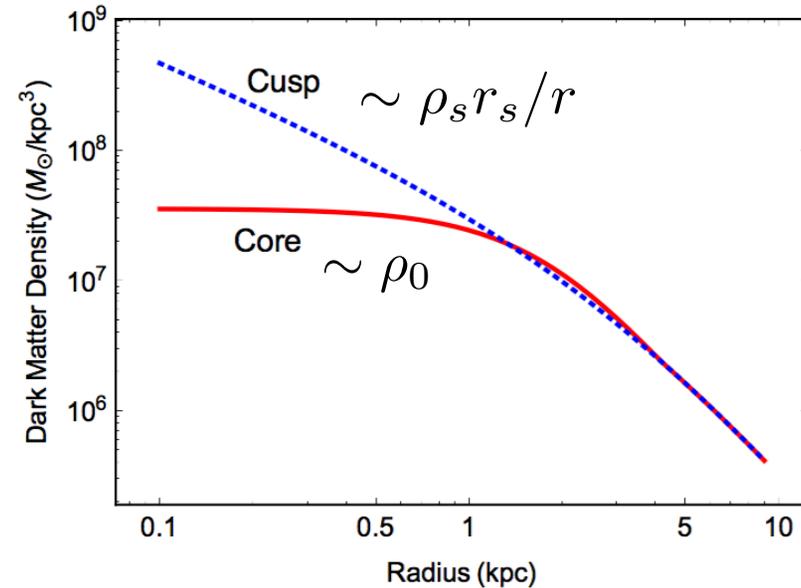
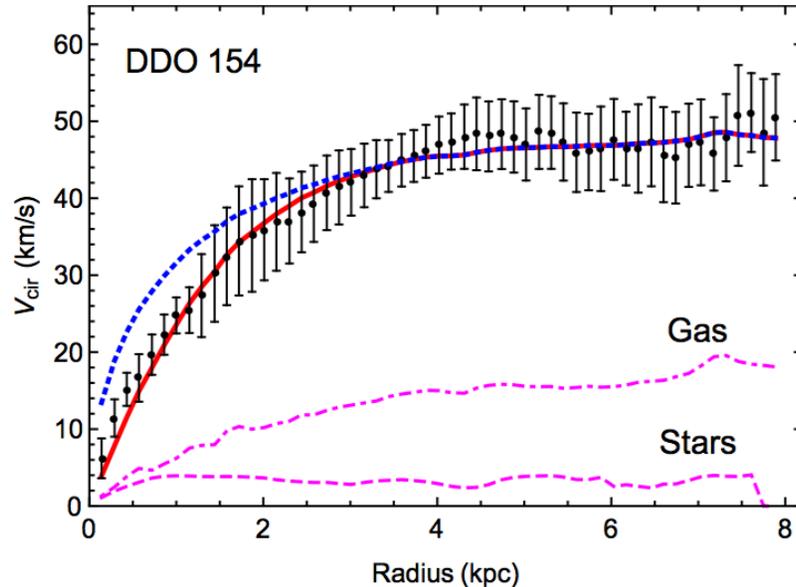
Diversity

Missing Satellites

Too-Big-To-Fail

Core vs. Cusp Problem

- DM-dominated systems (dwarfs, LSBs)

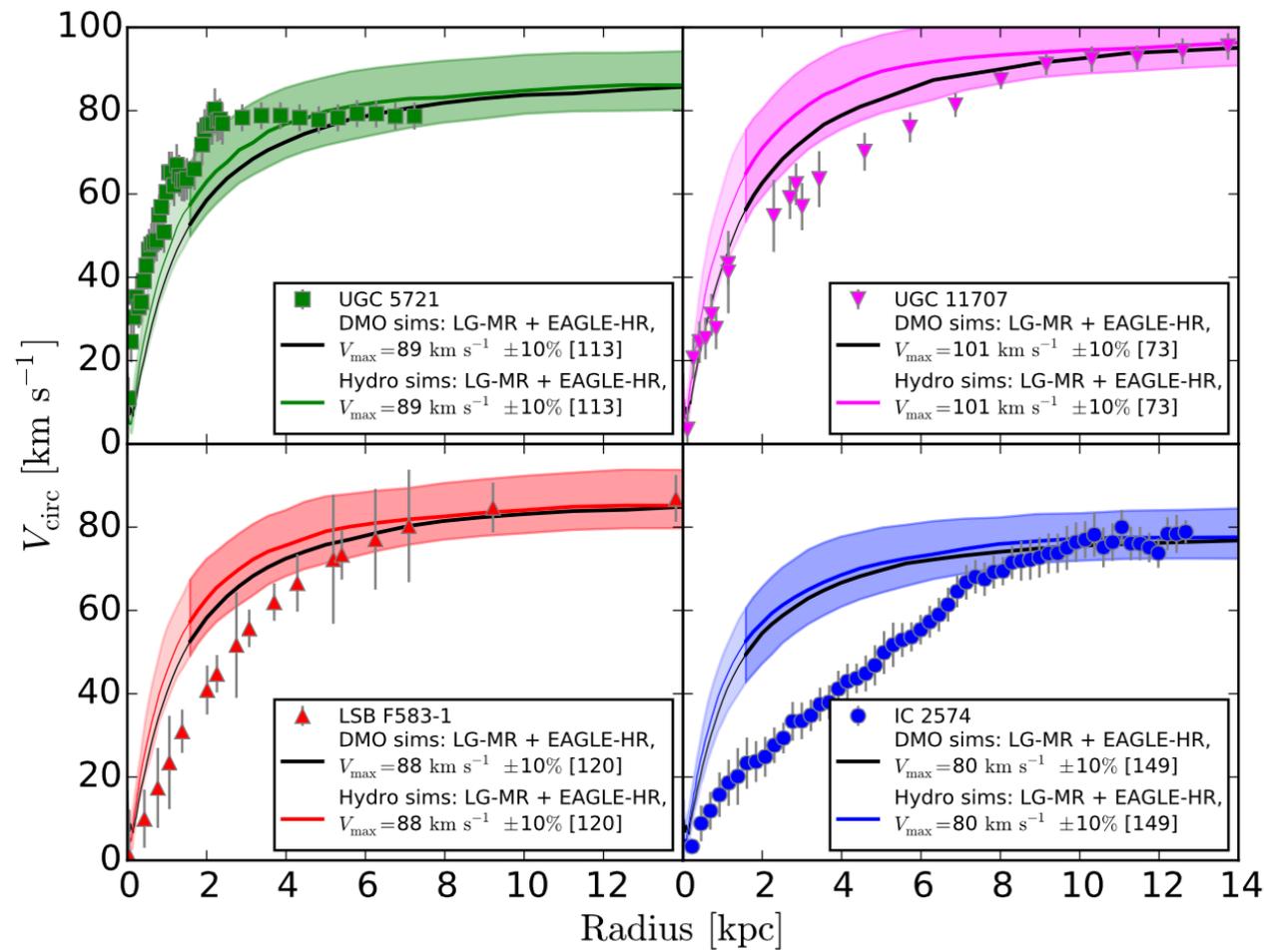


$$\frac{\rho_s}{r/r_s(1+r/r_s)^2}$$

universal density profile, NFW profile
 ρ_s and r_s are strongly correlated

The Diversity Problem

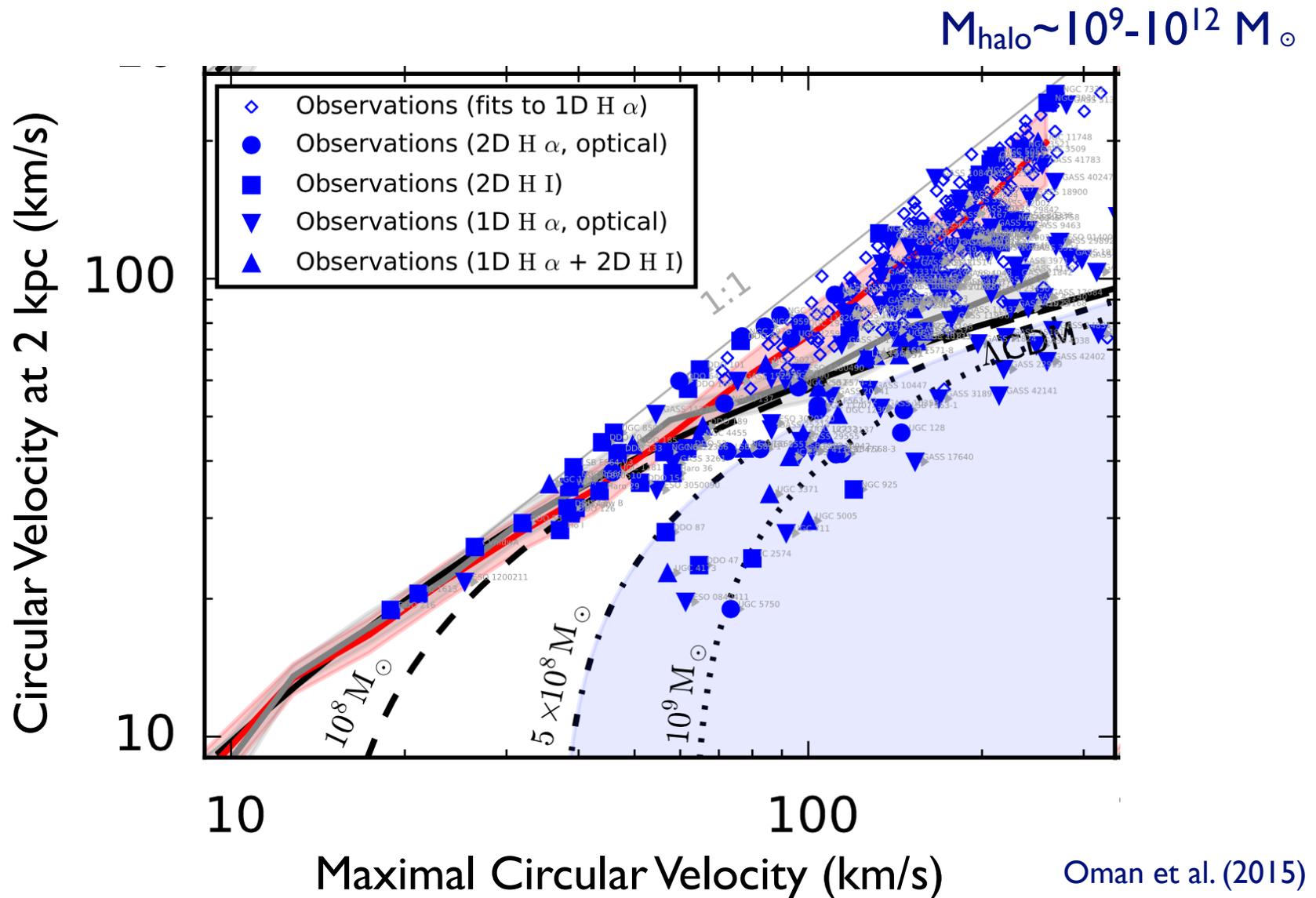
- The diversity of spiral galaxies



Oman et al. (2015)

Kuzio de Naray et al. (2009)

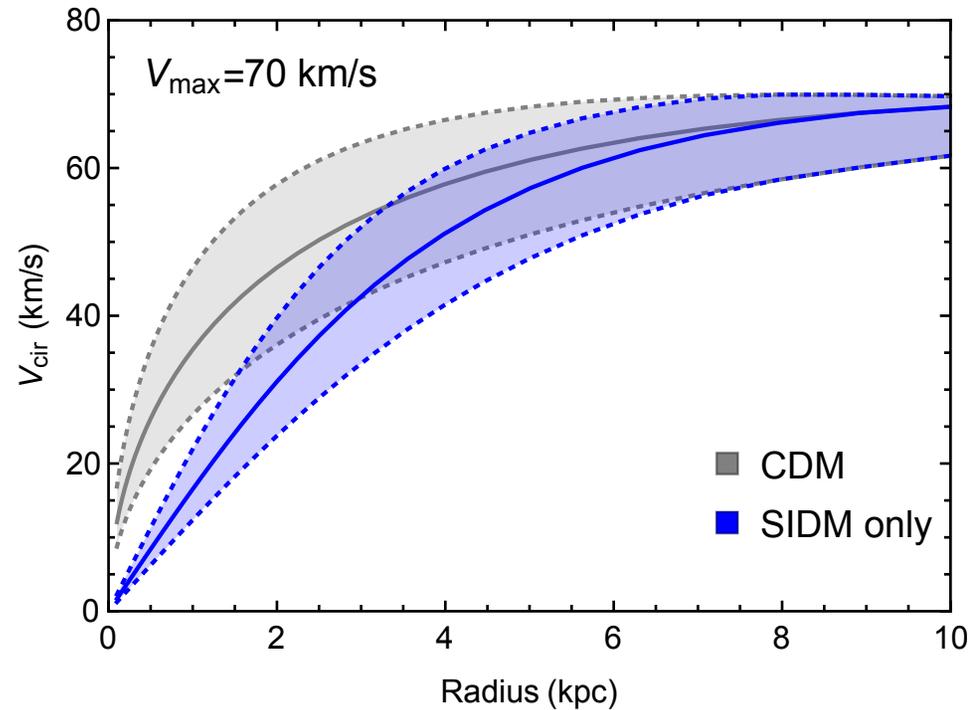
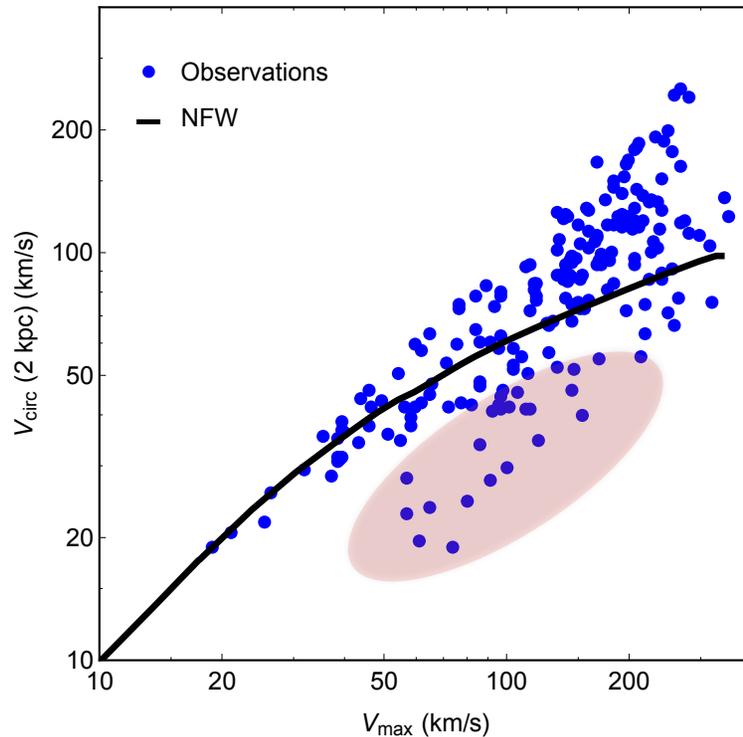
The Diversity Problem



$V_{\text{circ}}(2\text{kpc})$ has a factor of 3-4 scatter for a fixed V_{max}

Dark Matter Self-Interactions

- DM self-interactions thermalize the inner halo



DM-dominated galaxies: Lower the central density and the circular velocity

Isothermal
distribution

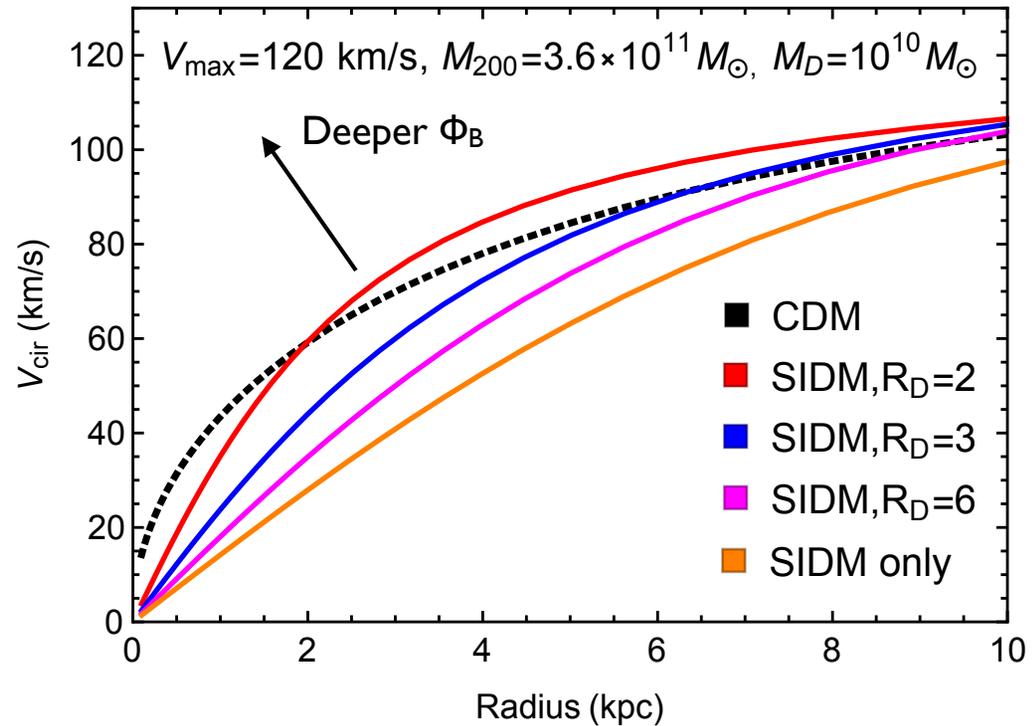
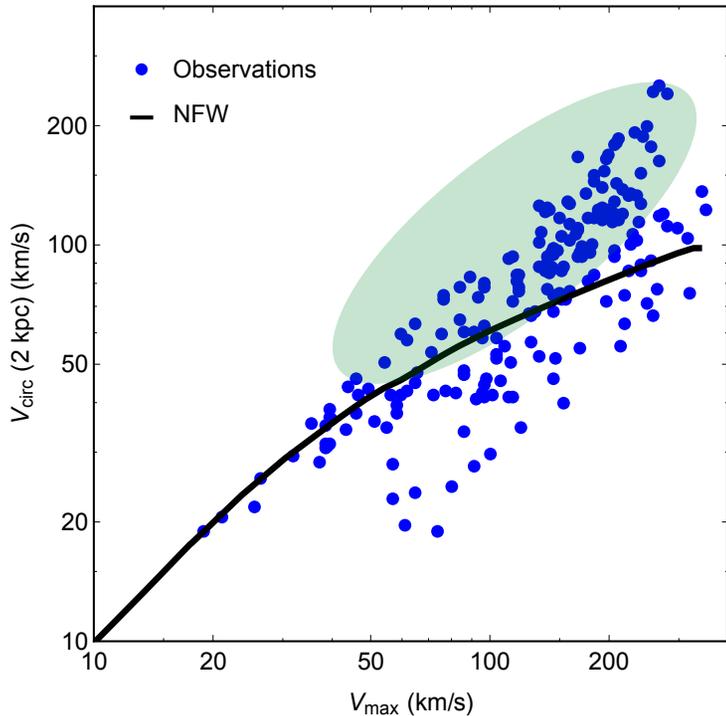
$$\rho_X \sim e^{-\Phi_{\text{tot}}/\sigma_0^2} \sim e^{-\Phi_X/\sigma_0^2}$$

Ideal gas: $PV=nRT$

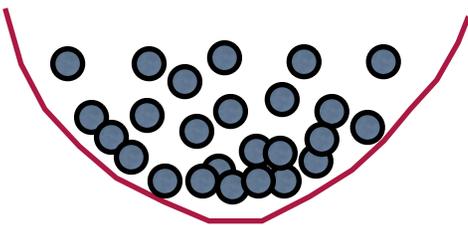
With Kamada, Kaplinghat, Pace (2016)

High Luminous Galaxies

- DM self-interactions tie DM together with baryons



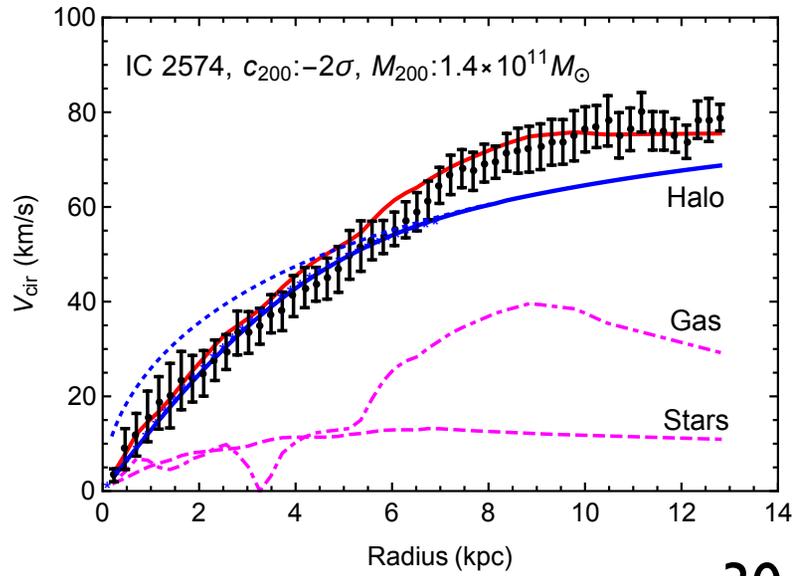
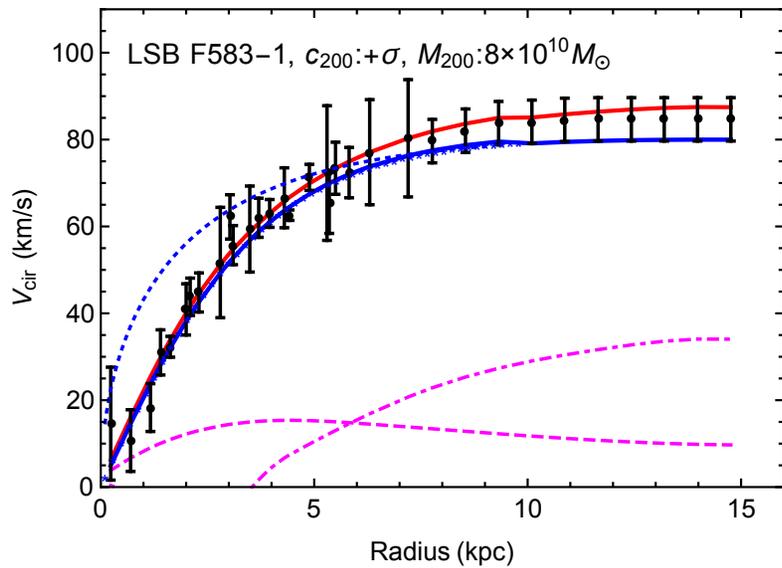
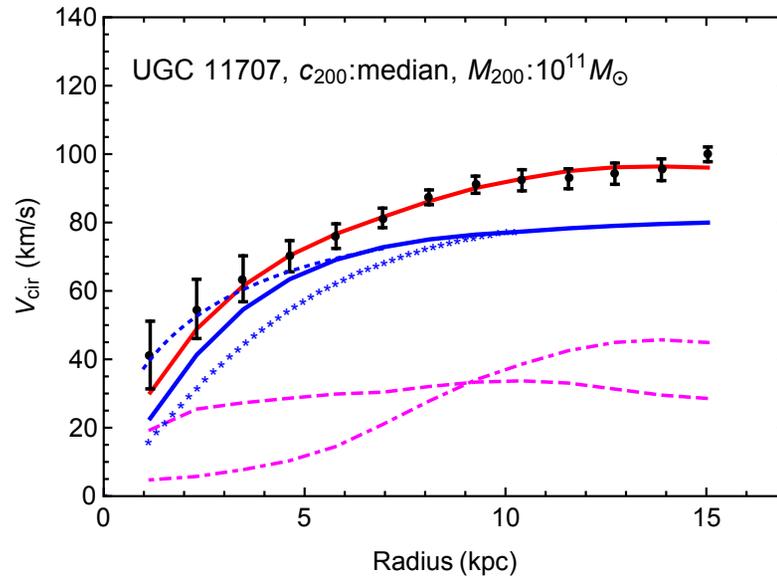
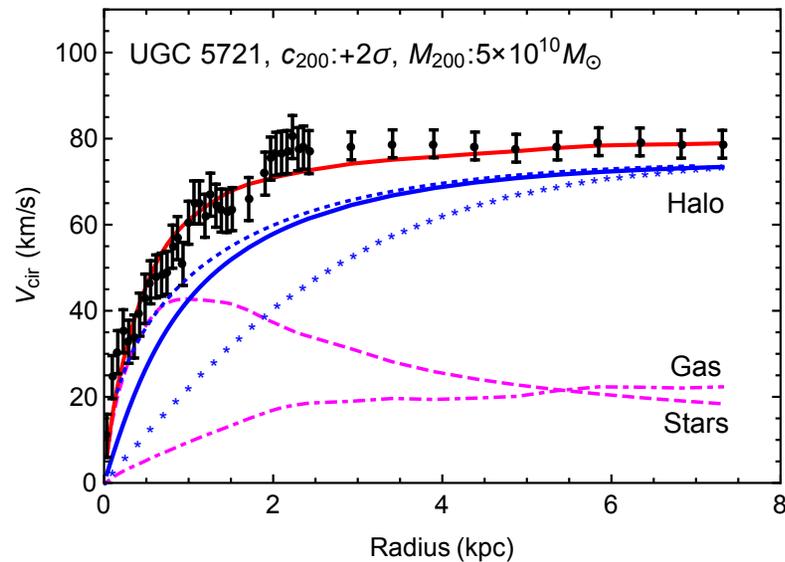
Thermalization leads to higher DM density due to the baryonic influence



$$\rho_X \sim e^{-\Phi_{\text{tot}}/\sigma_0^2} \sim e^{-\Phi_B/\sigma_0^2}$$

With Kamada, Kaplinghat, Pace (2016)

- Explaining the diversity problem in SIDM

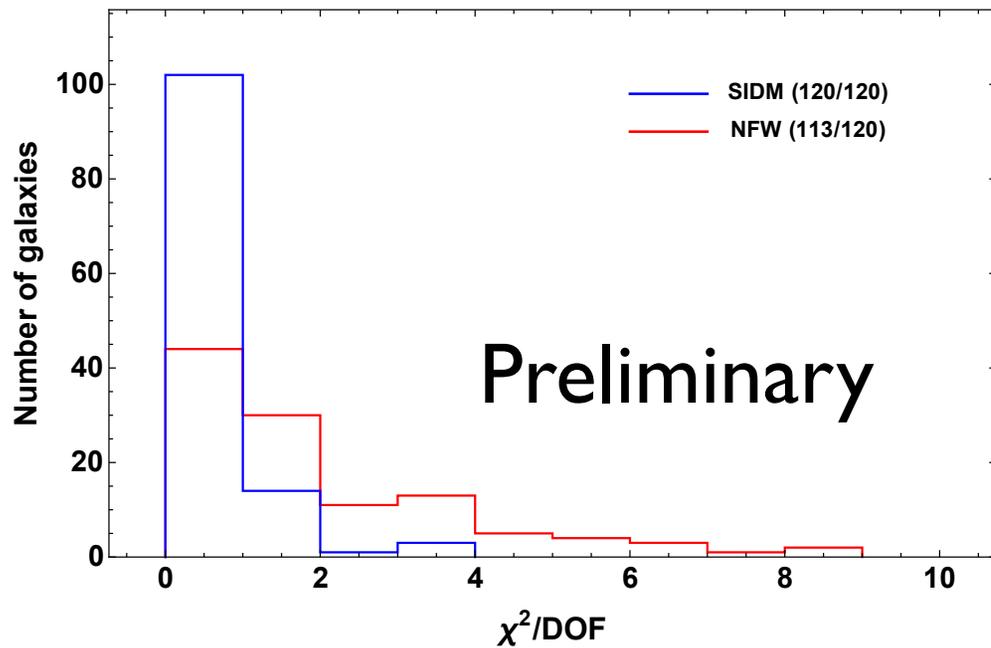


With Kamada, Kaplinghat, Pace (2016)

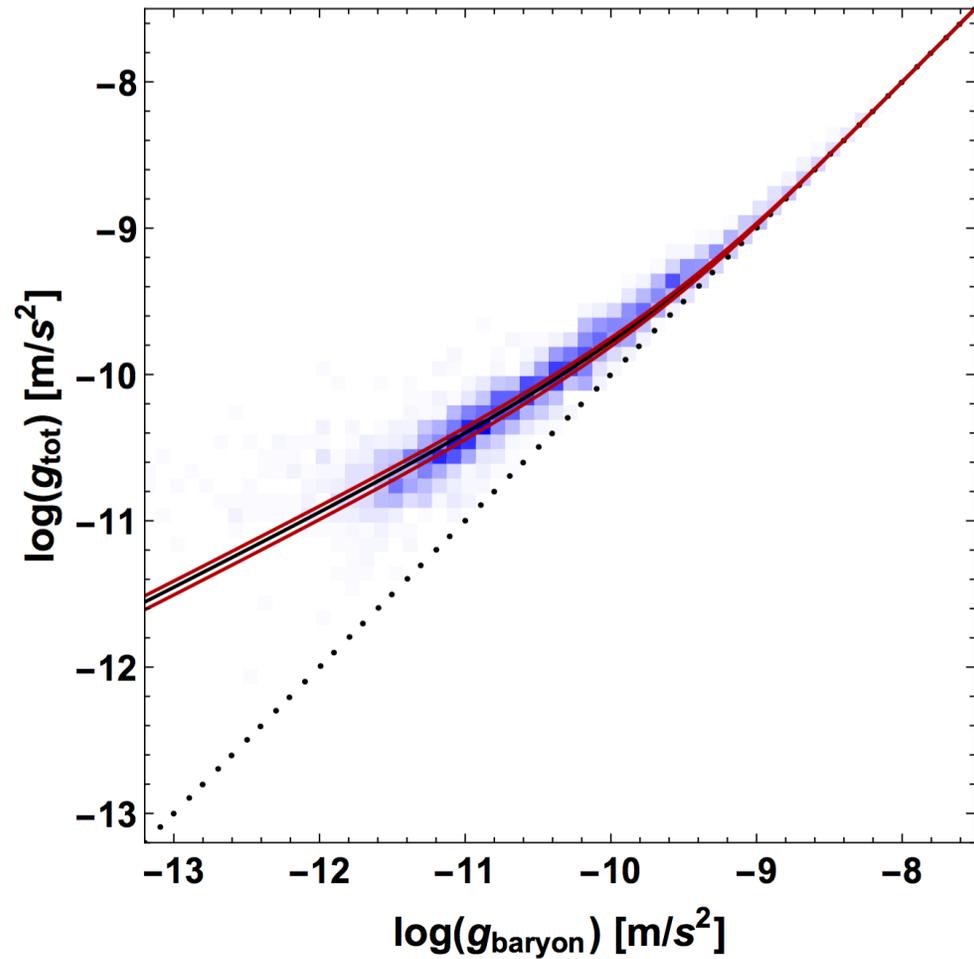
Simulations: Creasey et al. (2016)

30 galaxies

More Galaxies...

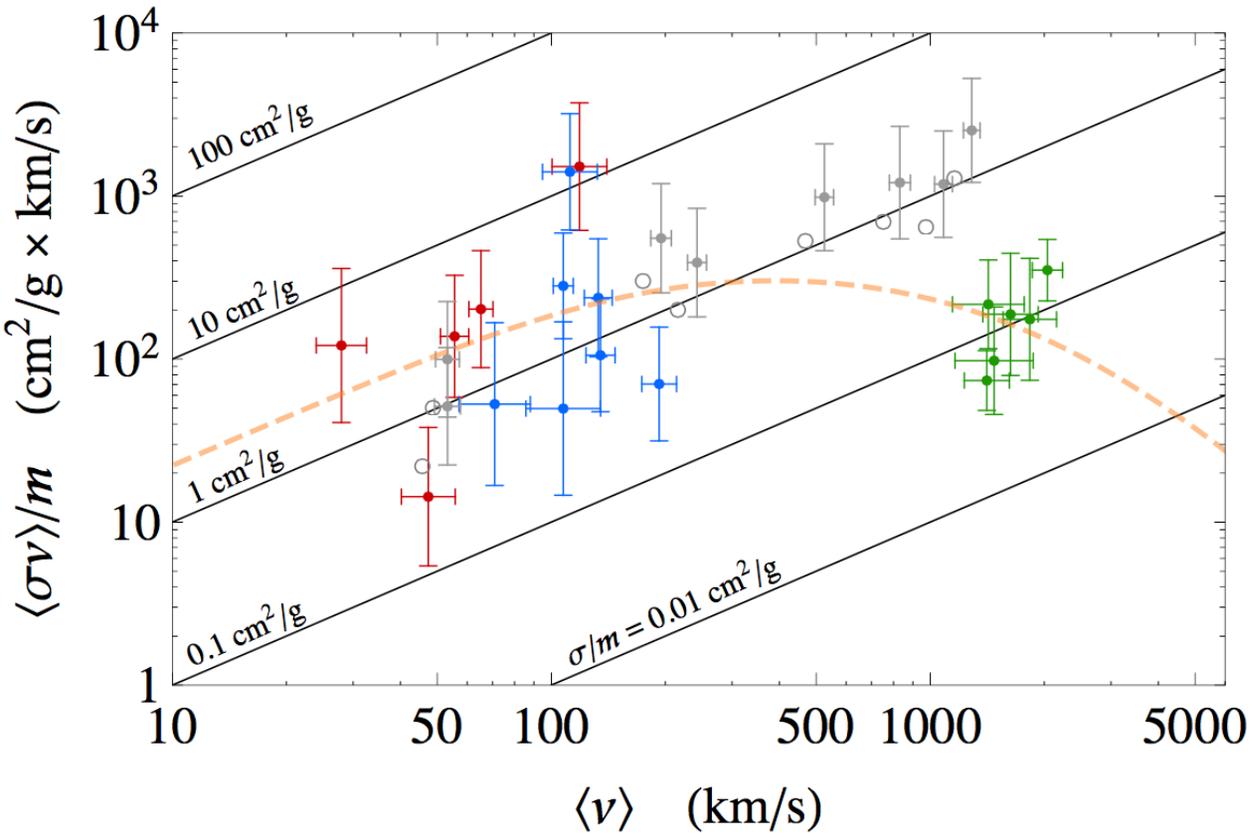


~120 spiral galaxies

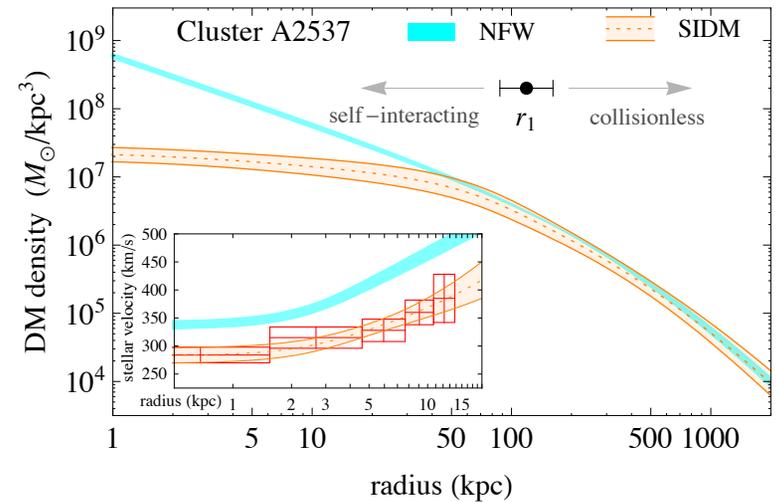


With Kaplinghat, Pace, Ren (in preparation)

SIDM from Dwarfs to Clusters



need velocity-dependent cross section



Core size in clusters: ~ 10 kpc

Clusters: ~ 0.1 cm²/g

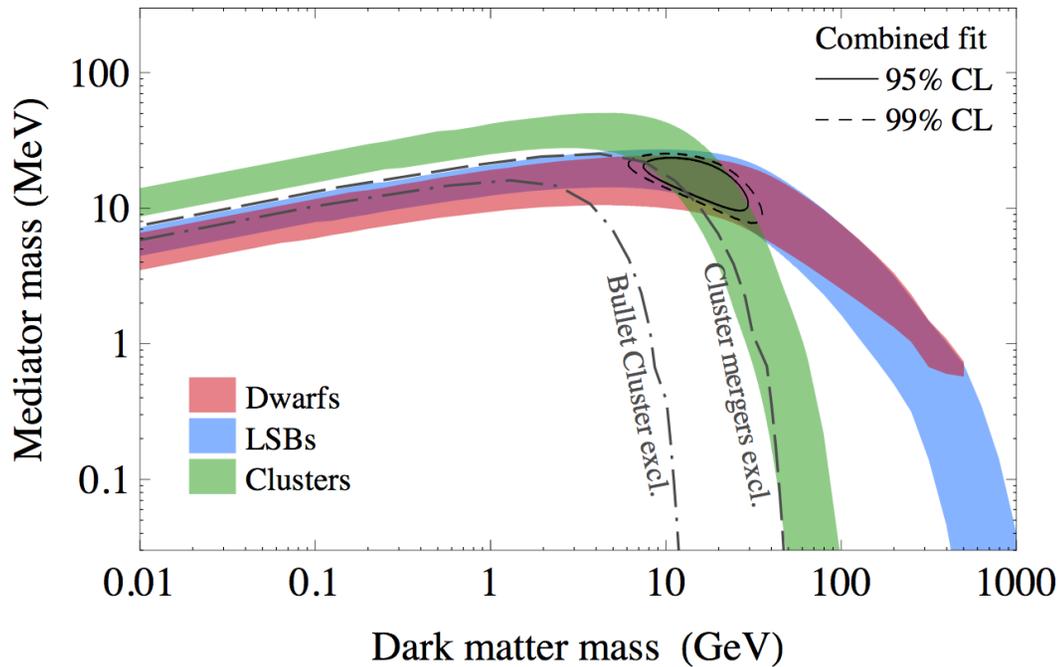
Galaxies: ~ 2 cm²/g

Bullet Cluster: < 2 cm²/g

With Kaplinghat, Tulin (PRL 2015)

Measuring Dark Matter Mass

- Self-scattering kinematics determines SIDM mass



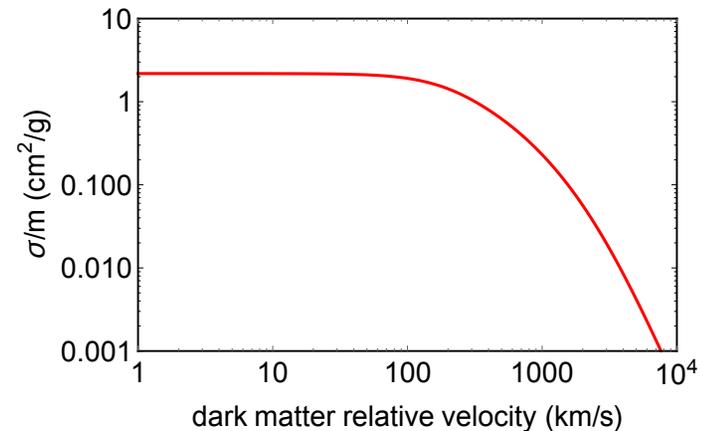
$$\alpha_X = 1/137$$

$$m_X: \sim 15 \text{ GeV}, m_\phi: \sim 17 \text{ MeV}$$

With Kaplinghat, Tulin (PRL 2015)

$$V(r) = \frac{\alpha_X}{r} e^{-m_\phi r}$$

$$m_X \ll m_\phi \quad 10^{-3} m_X \sim m_\phi$$



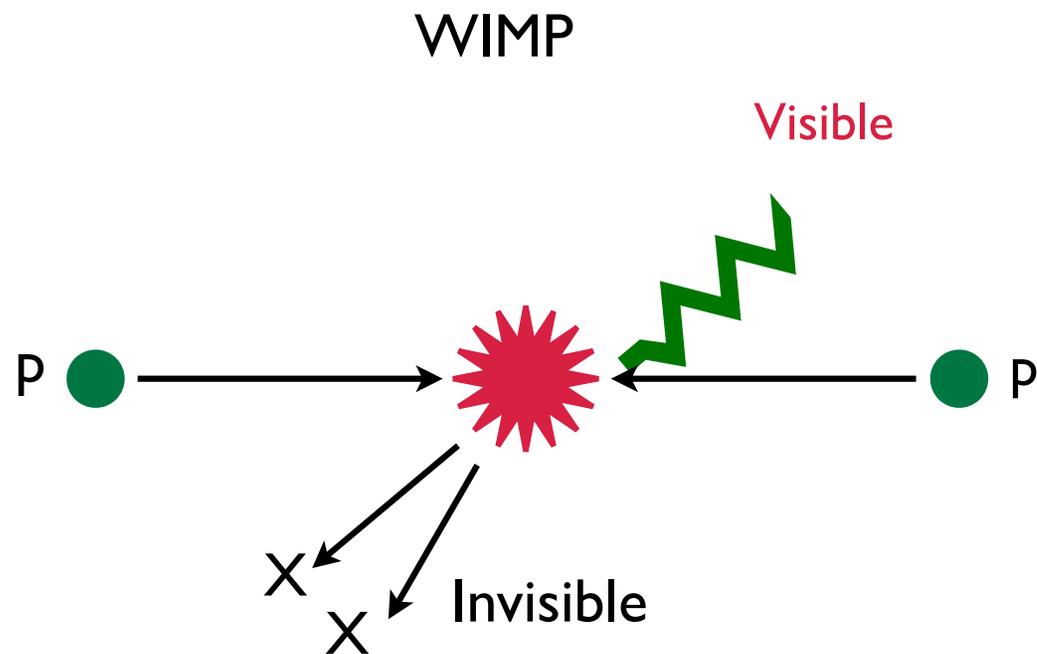
mild dependence on α_X

$$\alpha_X = 0.001 - 0.1$$

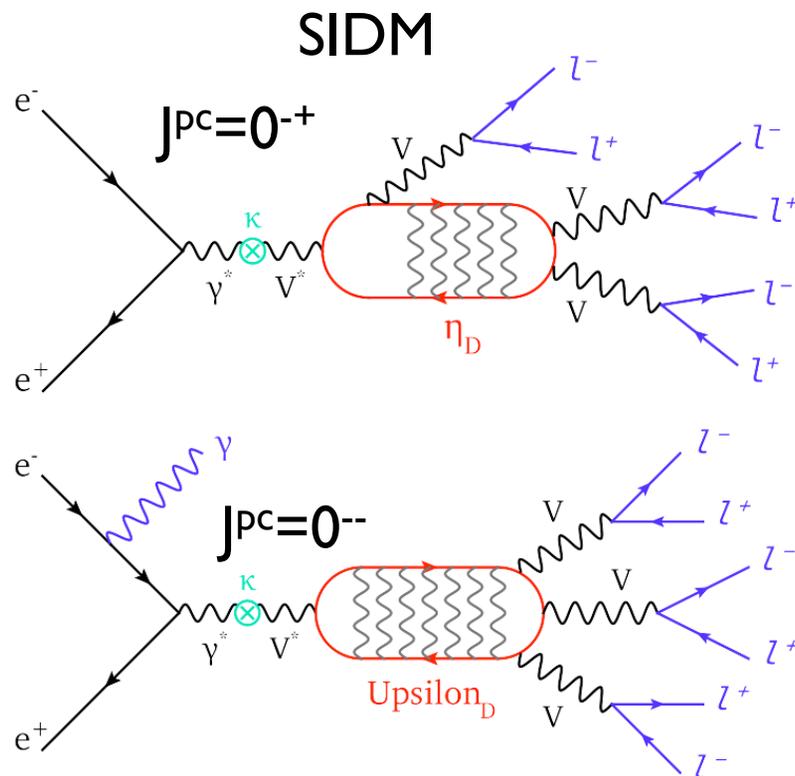
$$m_X: \sim 5-30 \text{ GeV}$$

SIDM at Colliders

- Striking collider signals



$pp \rightarrow \text{Monojet} + \text{Missing Energy}$



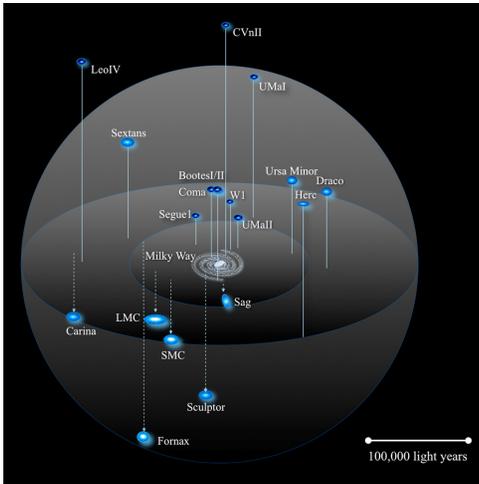
An, Echenard, Pospelov, Zhang (PRL 2015)

Tsai, Wang, Zhao (PRD 2015)

Shepherd, Tait, Zaharijas (PRD 2009)

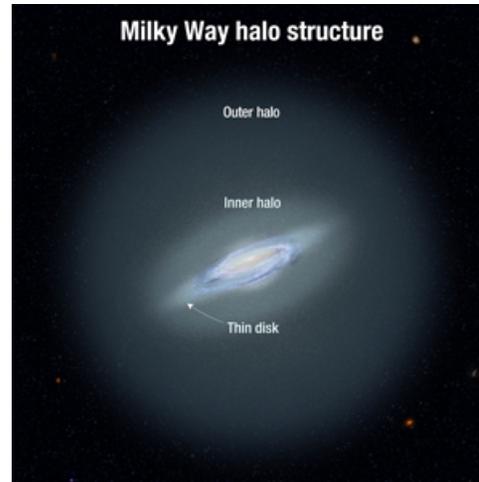
Dark Matter “Colliders”

Dwarf galaxies



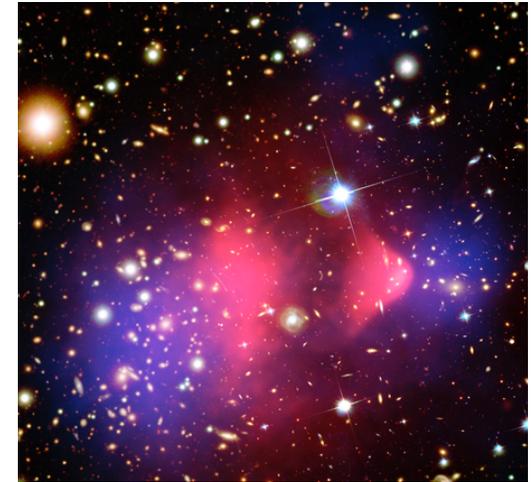
“B-factory” ($v \sim 30$ km/s)

MW-size galaxies



“LEP” ($v \sim 200$ km/s)

Clusters



“LHC” ($v \sim 1000$ km/s)

Observations
on all scales

Self-scattering
kinematics



Measure particle
physics parameters
 σ_x, m_x, g_x