

News from (/in/about) the dark

Episode 4:

WANTED: Dark matter clustering properties from subgalactic to cosmological scales

Montpellier – May 20-22 2019



WELCOME!

Julien Laval
CNRS
LUPM-Montpellier, Theory Group

News from/in/about the Dark (4)
Montpellier, May 20-22 2019

***SOC:** Benoit Famaey, JL.*
***LOC:** Gaétan Facchinetti, JL, Vivian Poulin, Martin Stref*
Secretary (travel/stay): Lydie Le Clainche
Secretary (logistic): Amel Chennouf

Practical

- **Monday-Tuesday: Amphi 10.01**
- **Wednesday: Amphi 12.01 (2 blocks from here)**
- **Lunches: buffet in the garden (caterer)**
- **WIFI: network is “UM-Net”, then try [login and pwd written on folder](#).**
- **.... or EDUROAM**
- **Dinners:**
 - **Monday: free (enjoy the city center)**
 - **Tuesday: [social dinner at Le Petit Jardin](#) (20, rue Jean-Jacques Rousseau)**
- **Goodies: a pack available at the entrance**
- **Any question? Ask Gaétan, Martin, Vivian, or myself.**

Institutional acknowledgments

Funding for **interdisciplinary theoretical networking project “Galactic Dark Matter”** 2017-2022 (participants from French institutes mostly).

- CNRS/IN2P3-Theory
- CNRS/INSU national programs for cosmology/high-energy astrophysics
- ANR project GaDaMa

Workshop series “News from the Dark”:

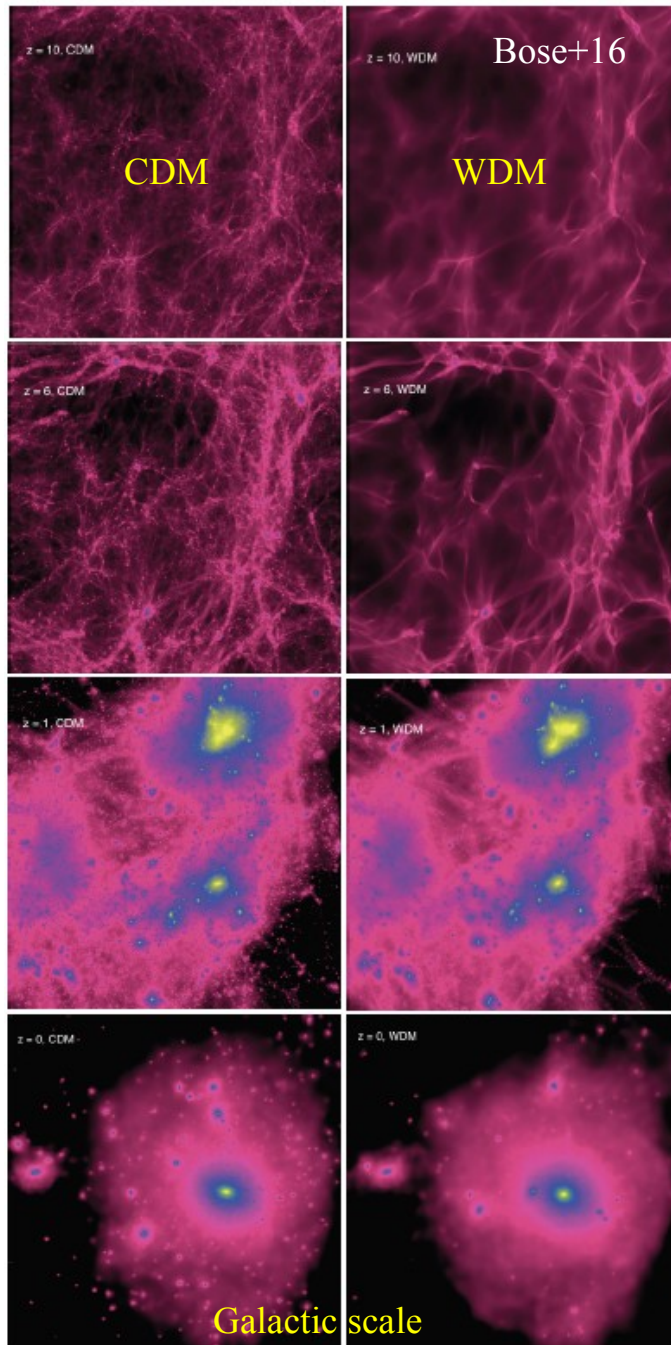
Address dark matter issues/searches from the Galactic to cosmological scales.

- Bring together astroparticle/particle physicists + astroph/cosmo experts in galactic dynamics, structure formation, and cosmological probes.
- On invitation (no registration) + a good balance of young scientists
- Long talks to present details of advanced topics (and show the dust under carpets + propaganda as moderate as possible ;-)).
- Interactive, collaborative, friendly.

Small change in 2019 program:

- Chervin Laporte sick
 - videocon or replaced by Benoit Famaey
 - moved to the end of today’s session
- + Arturo Nunez on Tuesday morning (testing recipes of star formation)

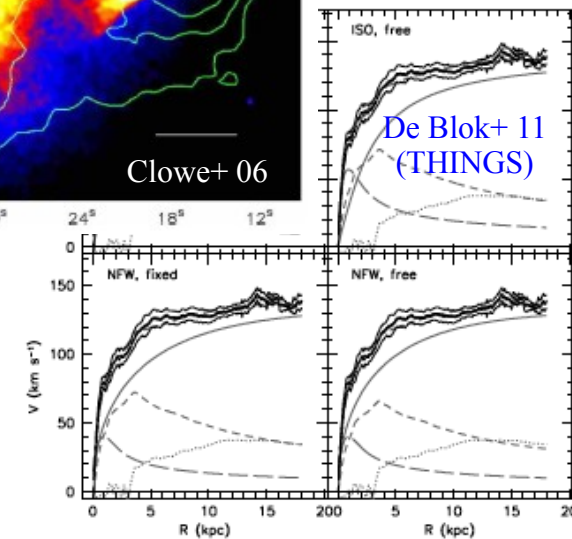
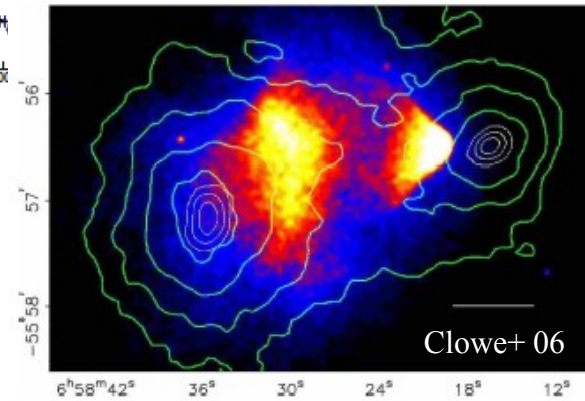
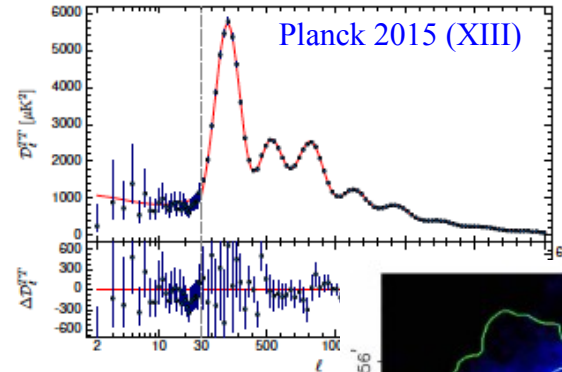
The cold Dark Matter (CDM) paradigm



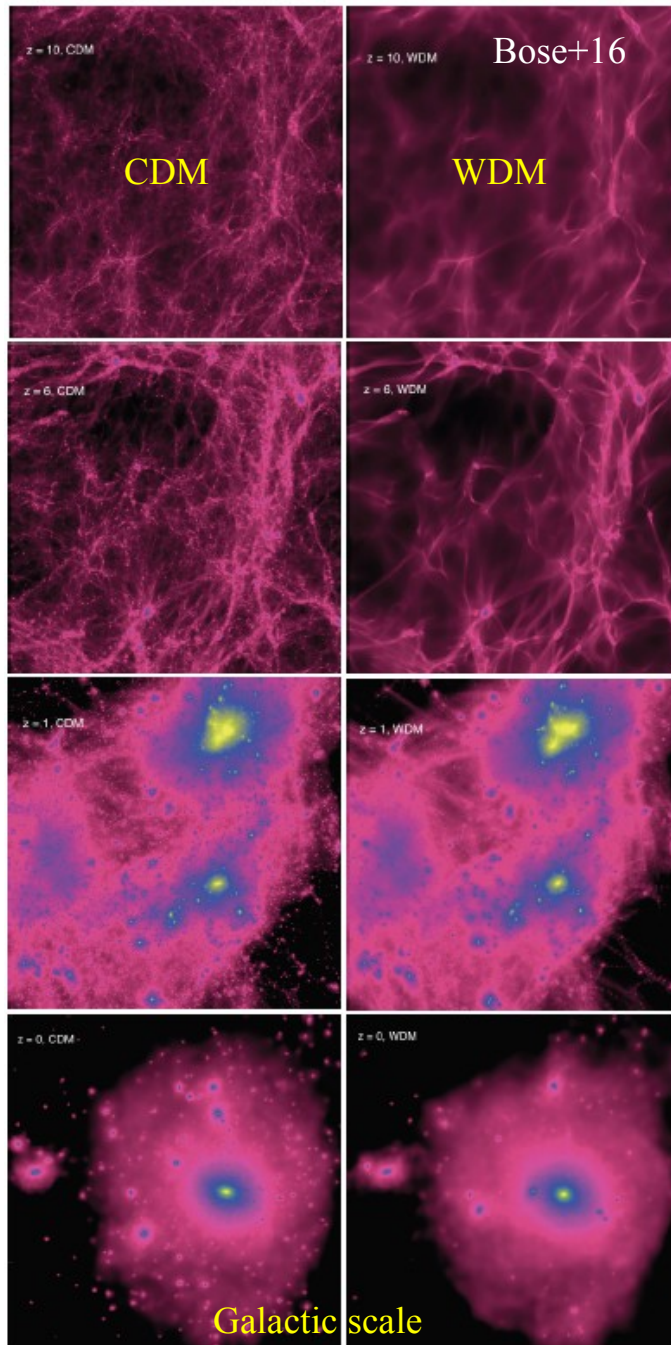
So far, only gravitational evidence for DM
(cosmological structures+CMB)

CDM successes:

- CMB peaks
- Successful structure formation (from CMB perturbations)
=> CDM seeds galaxies, galaxies embedded in DM halos
- Lensing in clusters + rotation curves of galaxies
- Also consistent with Tully-Fisher relation (baryonic physics)



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***A SERIOUS HINT OF NEW PHYSICS
BEYOND STANDARD PARTICLE PHYSICS AND/OR GENERAL RELATIVITY***

ISSUES:

- * **No DM particles identified so far**
(a generic statement for the dark universe: issue of the origin/s)
- * **How cold must it be?**
- * **Some observational issues on cosmological scales?** (e.g. Hubble tension)
- * **Some observational issues (challenges?) on small scales**

The origin of Dark Matter

*** Theoretical Particle Physics (a personal account)**

- **Self-confidence in BSM particle model building has stumbled on the LHC data (the famous hierarchy problem)**
- **Energy scale/s of new physics in particle physics no longer firmly predicted**
- **Still a few top-down motivated scenarios: QCD axions (very cold dark matter if so), sterile neutrinos**

=> Back to bottom-up approaches: simplified models (e.g. WIMP-like) with dark sectors (interaction mediators, etc.), effective field theory.

=> Driven by observations: 1) cosmological abundance 2) might solve CDM issues on small scales

=> Rich phenomenology: self-interactions, axion-like particles, ultra-light DM, etc. + many possible probes.

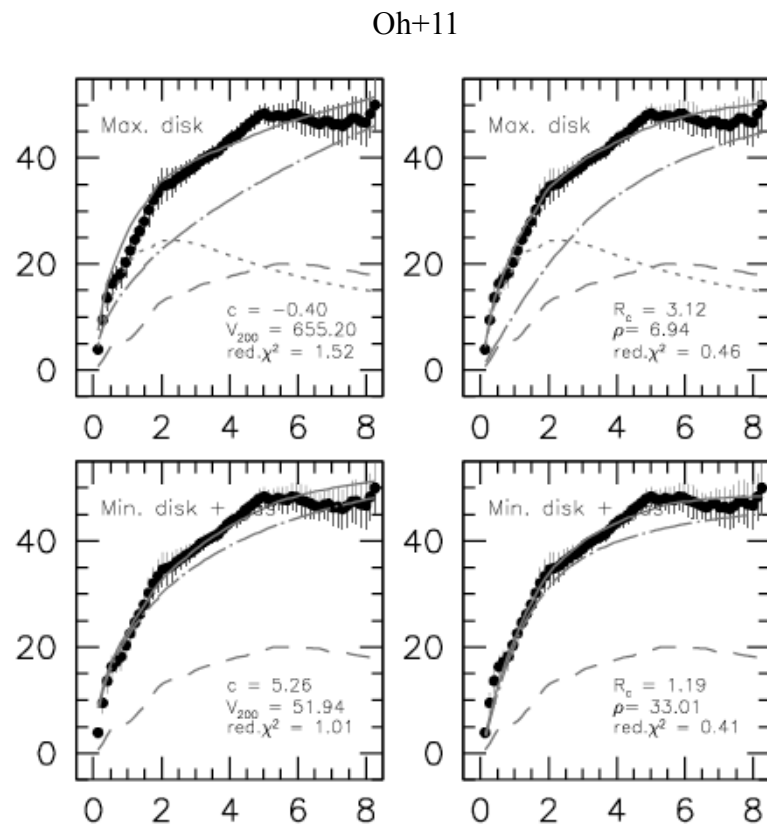
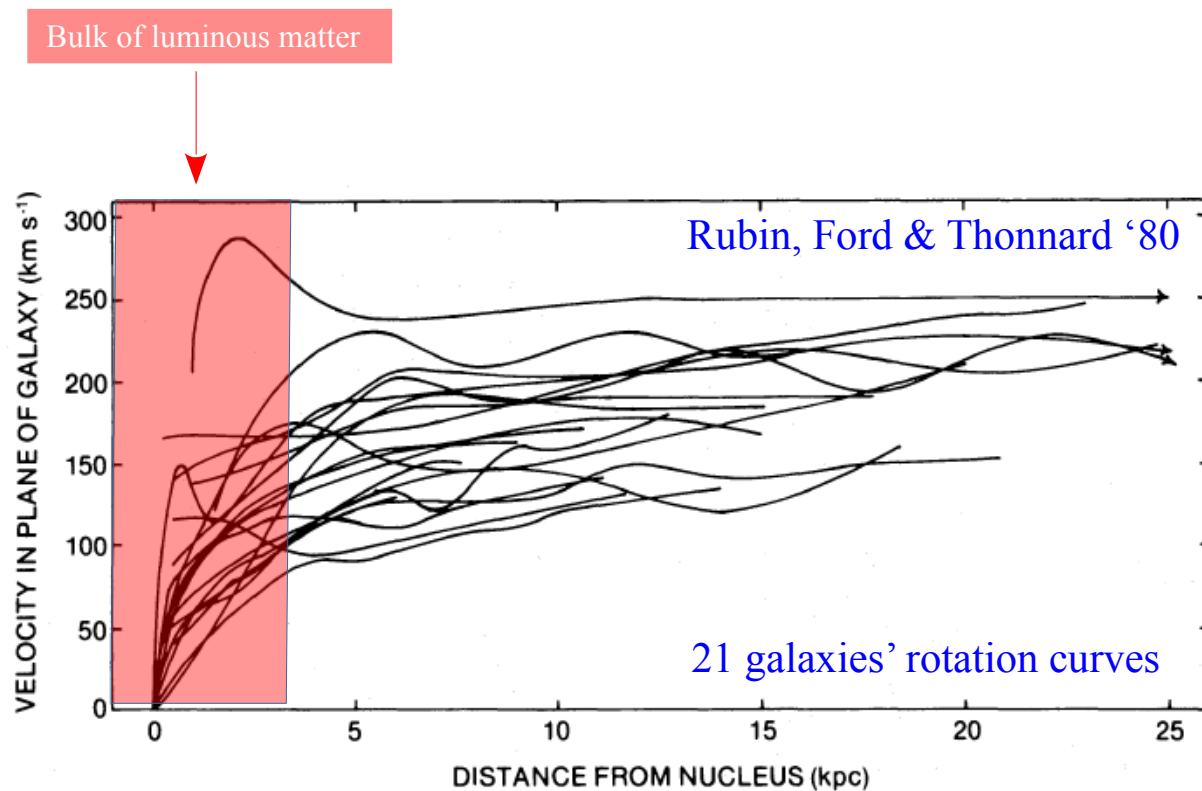
*** Theoretical Cosmology**

- **Scalar field cosmology (motivated by string theory or modified gravity)**
- **Primordial black holes (resurrected after LIGO/VIRGO events)**

*** Searches:**

- **Early/young universe (CMB, 21 cm, Ly-alpha)**
- **Structure formation (how cold? How interacting? Etc.)**
- **Galactic dynamics**
- **Astroparticle/astrophysical searches**
- **Laboratory**
- => Accurate predictions ↔ detailed understanding of all theoretical/environmental ingredients (a heavy program)**

Dark Matter on small (galactic) scales



Small scales probed not only by detailed observations of galaxies (e.g. the Milky Way!) ...
... but also with 21 cm, Ly-alpha, etc.

CDM issues on small (subgalactic) scales

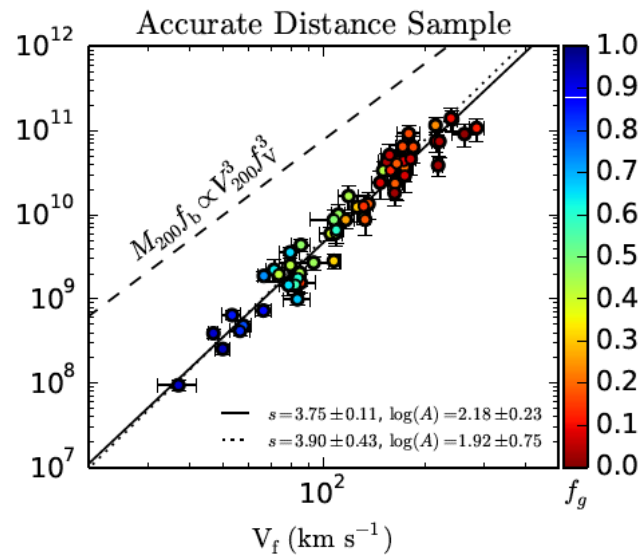
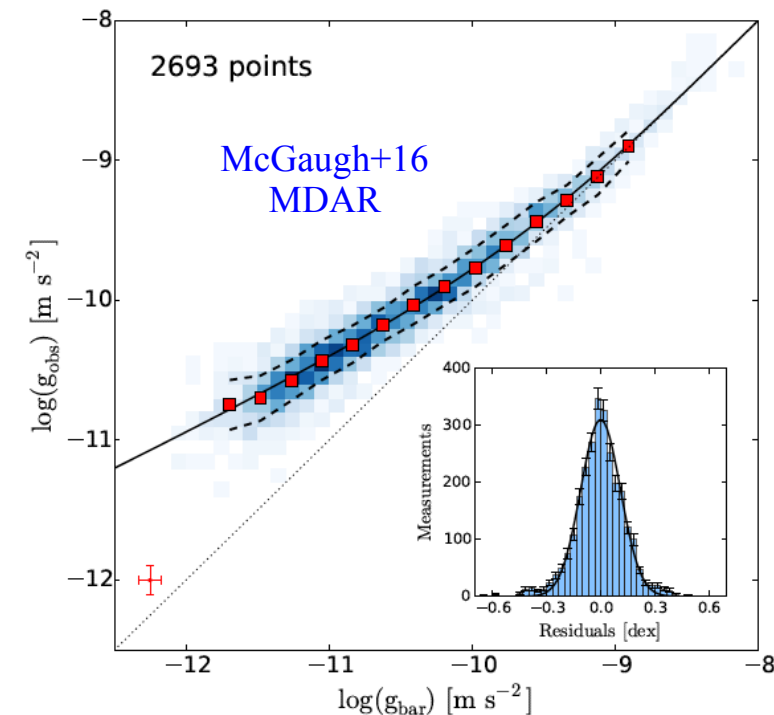
Small-Scale Challenges to the Λ CDM Paradigm

arXiv:1707.04256

James S. Bullock¹ and Michael Boylan-Kolchin²

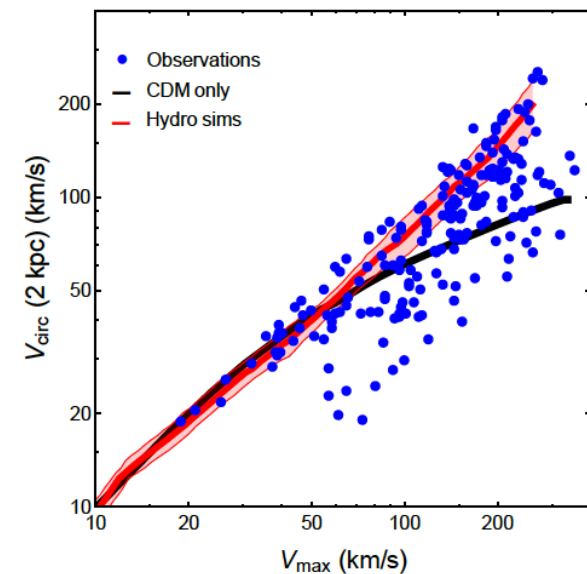
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²Department of Astronomy, The University of Texas at Austin, 2515 Speedway, Stop C1400, Austin, TX 78712, USA; email: mbk@astro.as.utexas.edu



Lelli+15, BTFR

Tulin+18 after Oman+15
Diversity problem



Core/cusp+diversity problems or regularity vs. diversity problems.
Maybe baryonic effects, but clear statistical answer needed.
Does same feedback recipe solve all problems at once?

CDM issues on small (subgalactic) scales

Small-Scale Challenges to the Λ CDM Paradigm

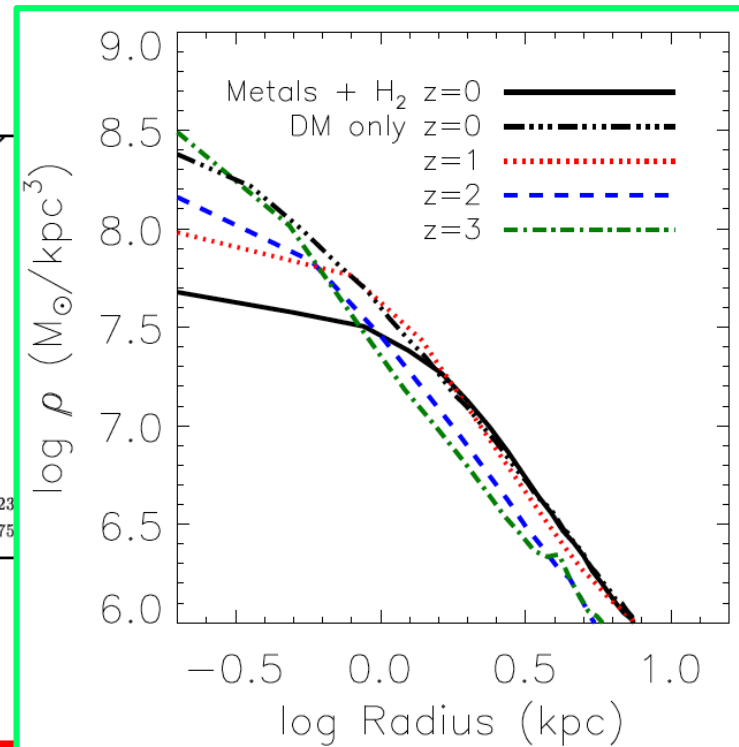
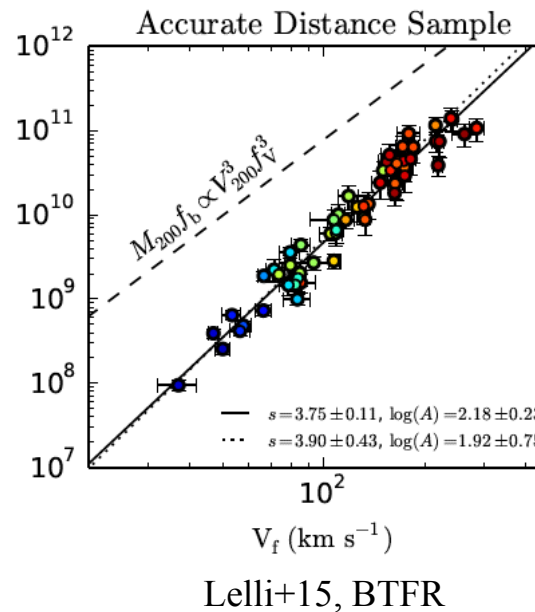
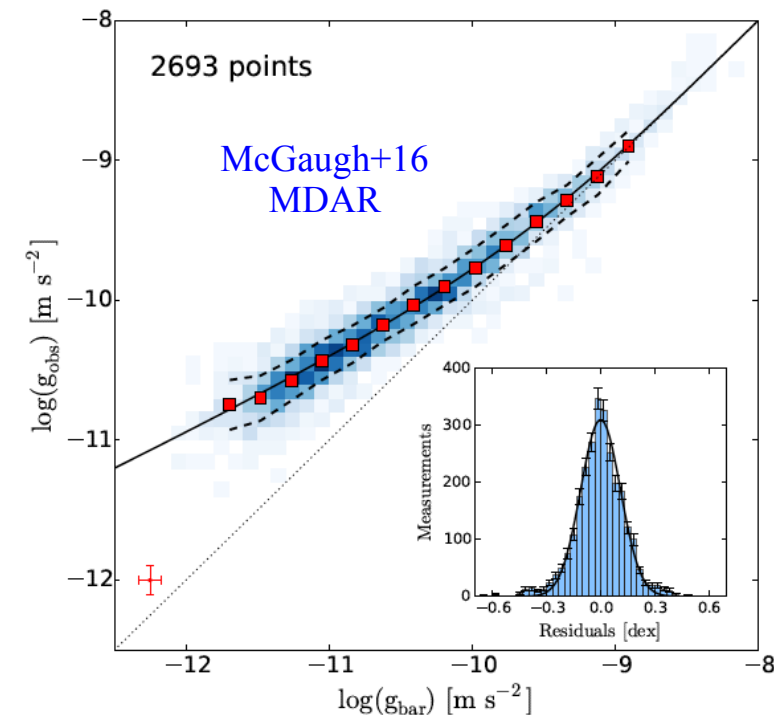
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Governato+12
Cusps \rightarrow cores



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How cold and structured is dark matter?

