A signature of sterile neutrino dark matter in the Local Universe

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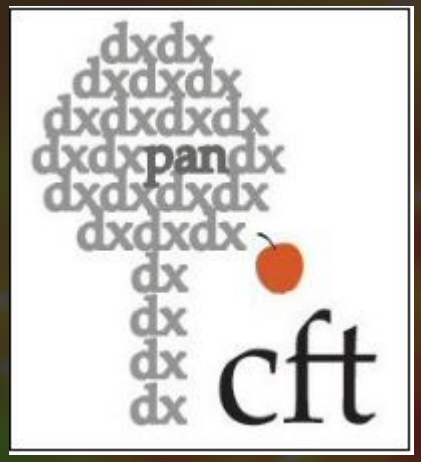

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Warsaw

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MARIE CURIE ACTIONS

Non-baryonic (particle) dark matter candidates

Type	Example	Mass
hot	neutrino	a few eV
warm	sterile ν majoron	keV-MeV
cold	axion neutralino	10^{-5}eV->1 00GeV

Incompatible with LSS and CMB!

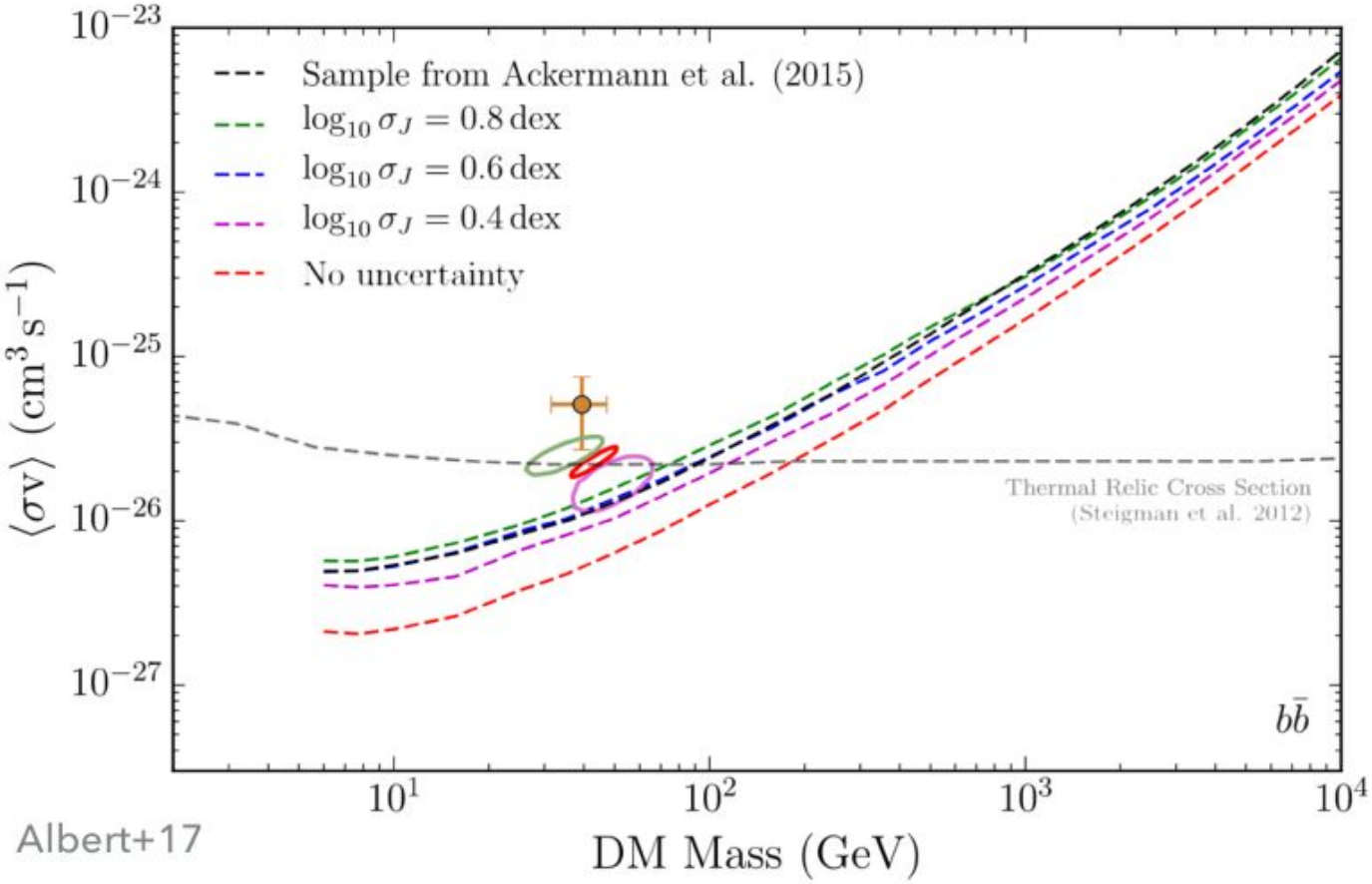
Non-baryonic (particle) dark matter candidates

Both CDM & WDM are compatible with CMB & LSS

Claims that both types of DM have been discovered:

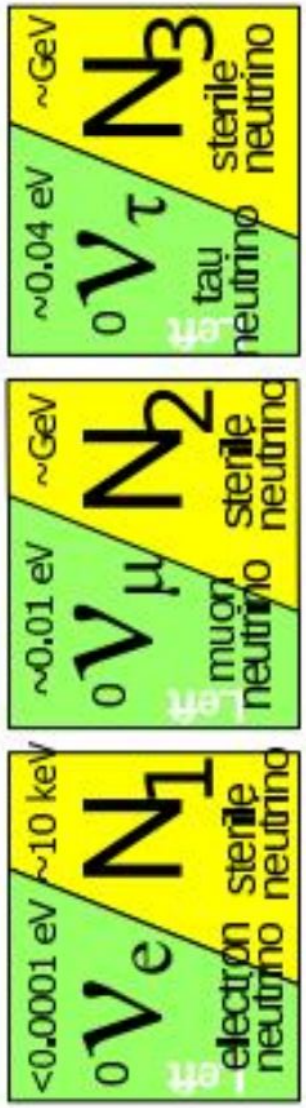
- CDM: γ-ray excess from Galactic Centre

- WDM (sterile ν): 3.5 keV X-ray line in galaxies and clusters



No detection of WIMPs

The WDM: sterile neutrino model fact sheet



Asaka+05/Laine+08/BRS+09

Competitive new dark matter models,(sterile neutrinos, self interacting models)

- **Warm** dark matter model
- Part of vMSM extension to standard model, facilitates neutrino oscillations, baryogenesis
- Two parameters, **mass** (M_s) & **lepton asymmetry** (L_6) ==> **matter power spectrum** & lifetime τ
- **7keV** sterile neutrino decay into X-ray + neutrino; an explanation for the 3.5keV line in clusters, M31, GC
- M_s=7keV: **L_6=[8-11]** (3.5keV line compatible)
- M_s=7keV: L_6=[120] (warmest model available for 7keV)

Sterile neutrino: potential channels for detection

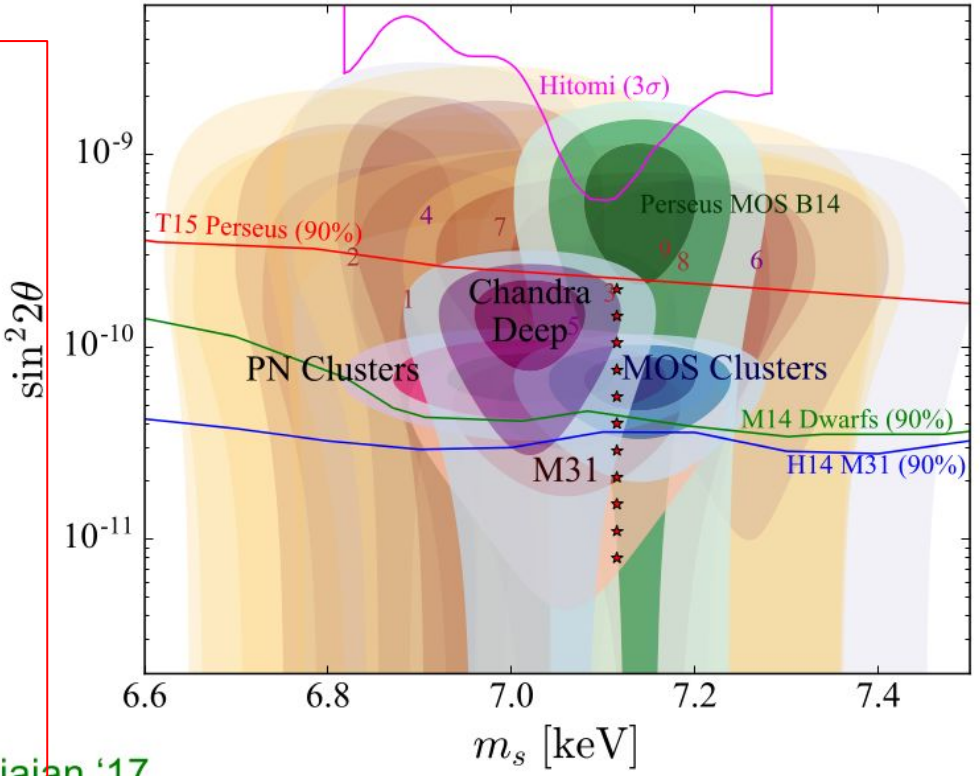
THE WAY FORWARD

Detect sterile neutrino and detect m_ν

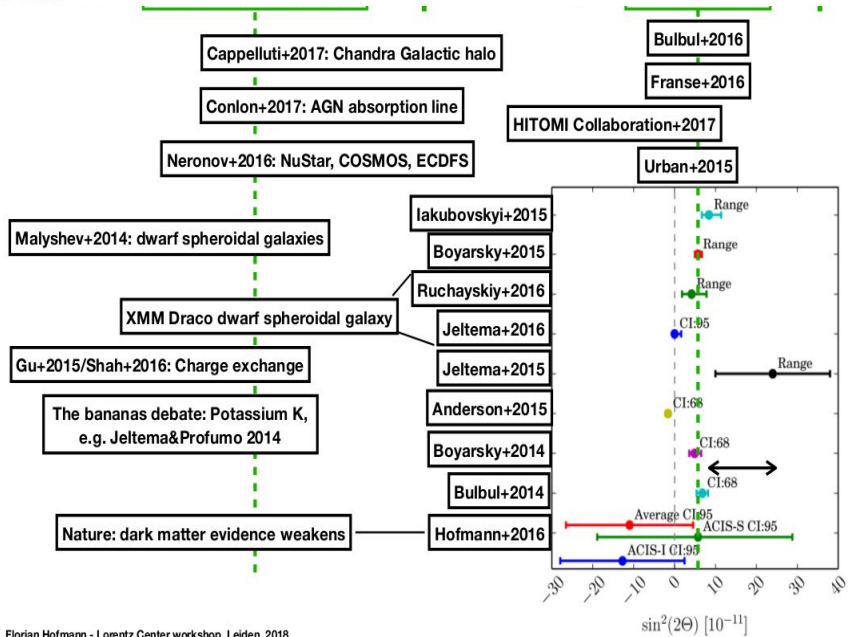
1. **Direct detection**
   If sterile neutrino mix with active neutrinos:
   Tritium β-decay - KATRIN

2. **Indirect detection**
   Detect of keV particles produces an X-ray line!

   Future X-ray missions:
   XARM - 2021 (replacement of Hitomi with soft X-ray spectrometer 0.3-12 keV)
   Athena - ~~2028~~ 2031 (0.5-12 keV High-res or large-area)



Abaziajan '17



SOTA galaxy formation simulations: Warm APOSTLE

- Gas hydrodynamics
- Electron cooling
- Chemical enrichment
- Star formation
- SN feedback
- SMBH formation
- AGN feedback
- Reionisation
- shock heating

VIRGO

Durham

ASPOSTOLE full hydro simulations

Local Group

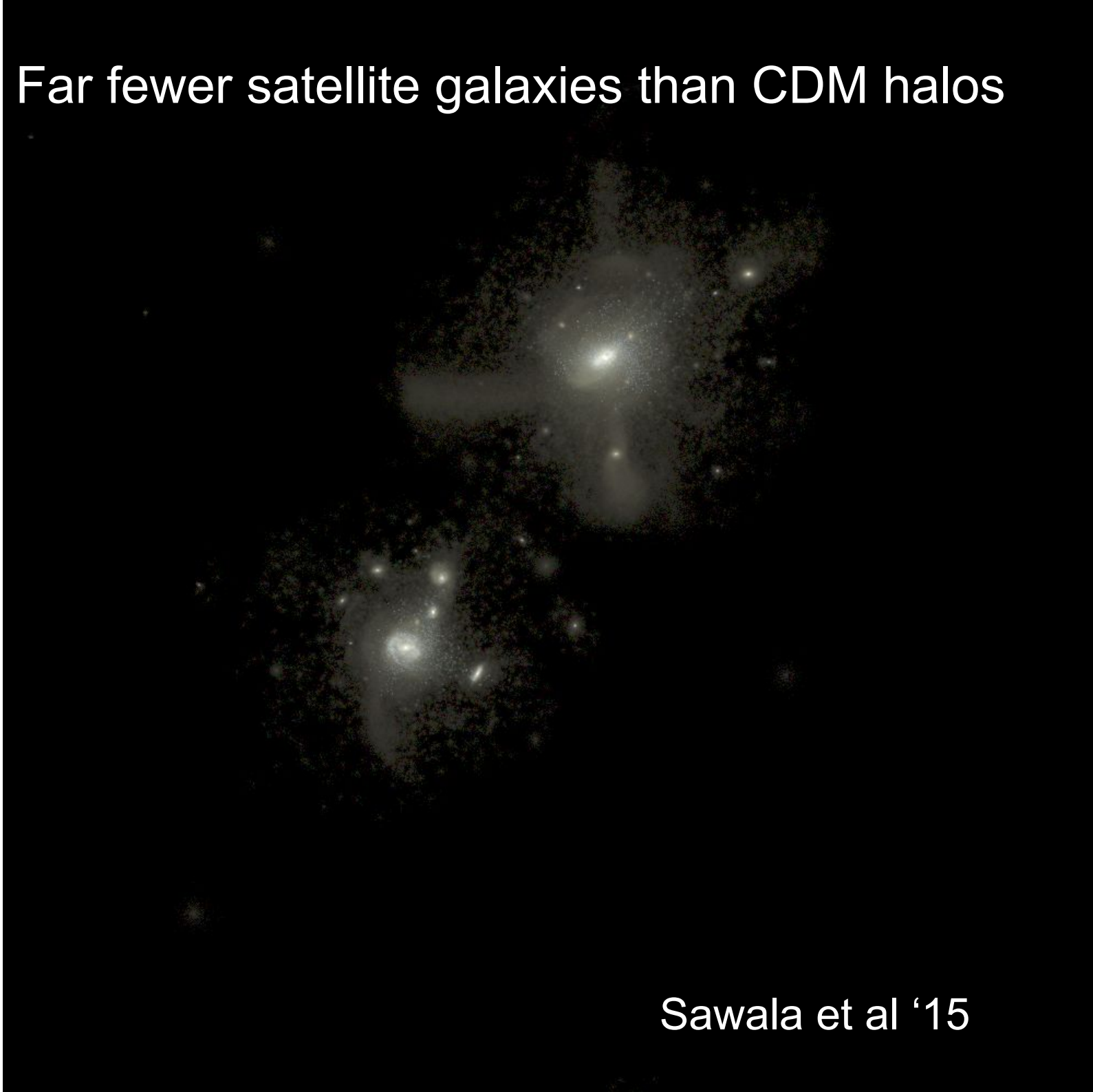
VIRGO

Durham

Far fewer satellite galaxies than CDM halos

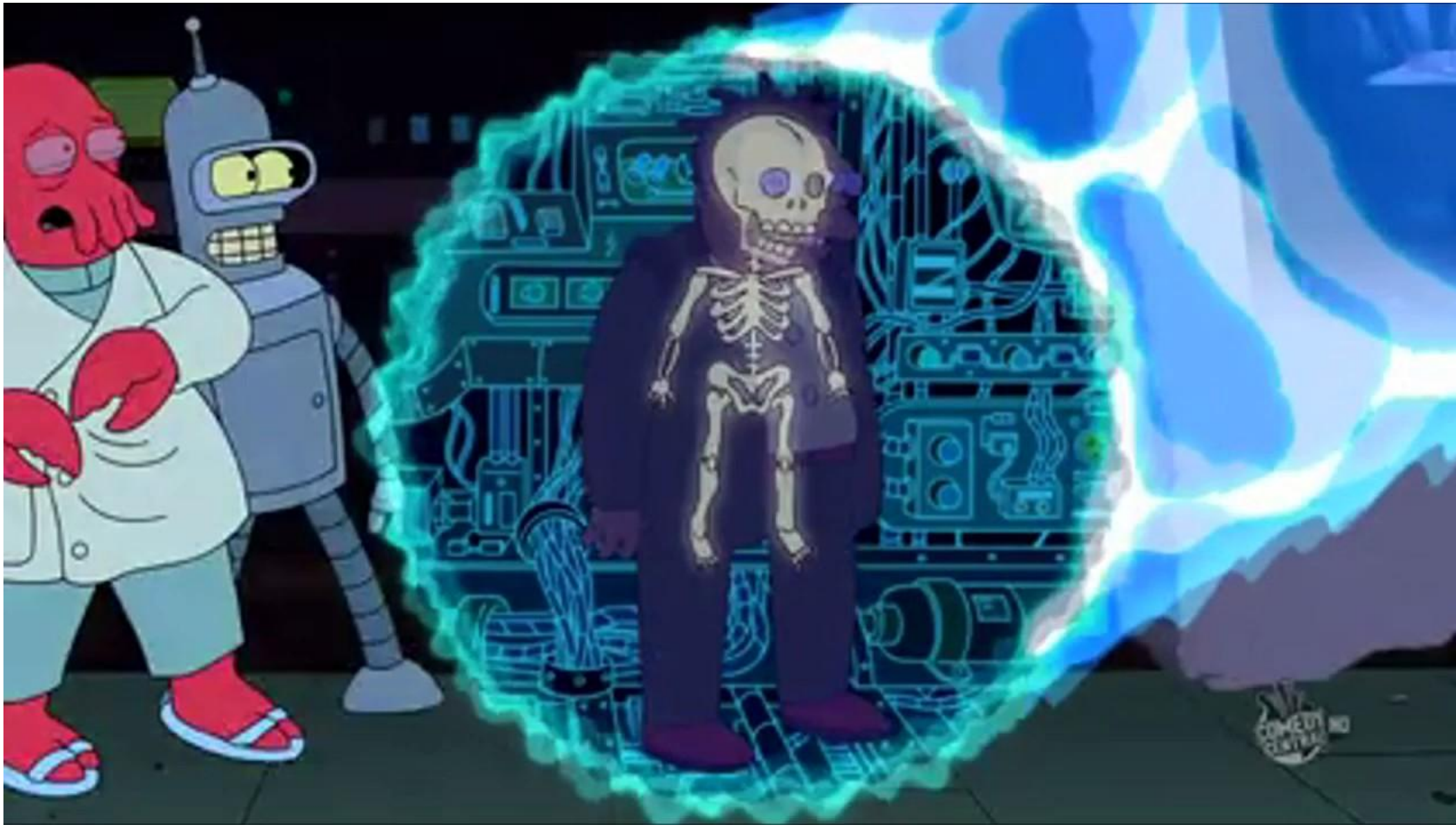
ASPOSTOLE full hydro simulations

Local Group



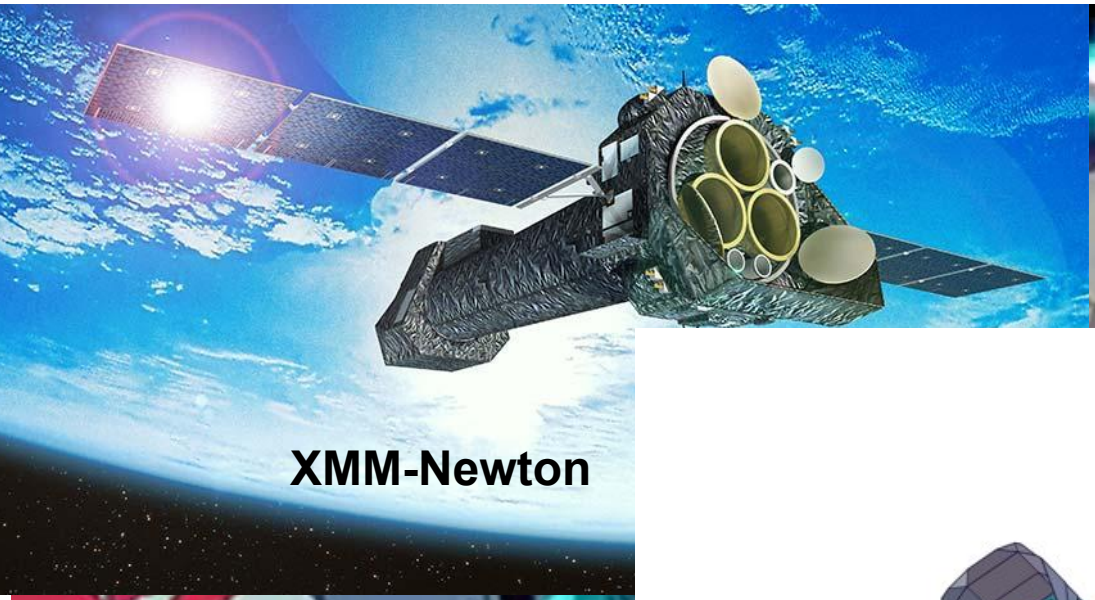
Sawala et al ‘15

The window for indirect detection



X-rays!

The window for indirect detection



XMM-Newton

Athena

XRISM

CDM and WDM X-ray decay fluxes

If there are N dark matter simulation particles in the FoV, the flux, F, is:

$$F = 1.18 \times 10^{20} \sum_{i=0}^{N} \frac{m_{\mathrm{DM},i}}{M_{\mathrm{DM}} \tau} \frac{1}{4\pi d_i^2} \text{ counts s}^{-1}\text{cm}^{-2} \qquad (1)$$

where d_i is the distance between the i-th particle and the observer in kpc, M_{DM} is the mass of the dark matter candidate particle in keV, τ is the particle lifetime in seconds and $m_{\mathrm{DM},i}$ is the mass of the i-th simulation dark matter particle in $\mathrm{M}_\odot$:

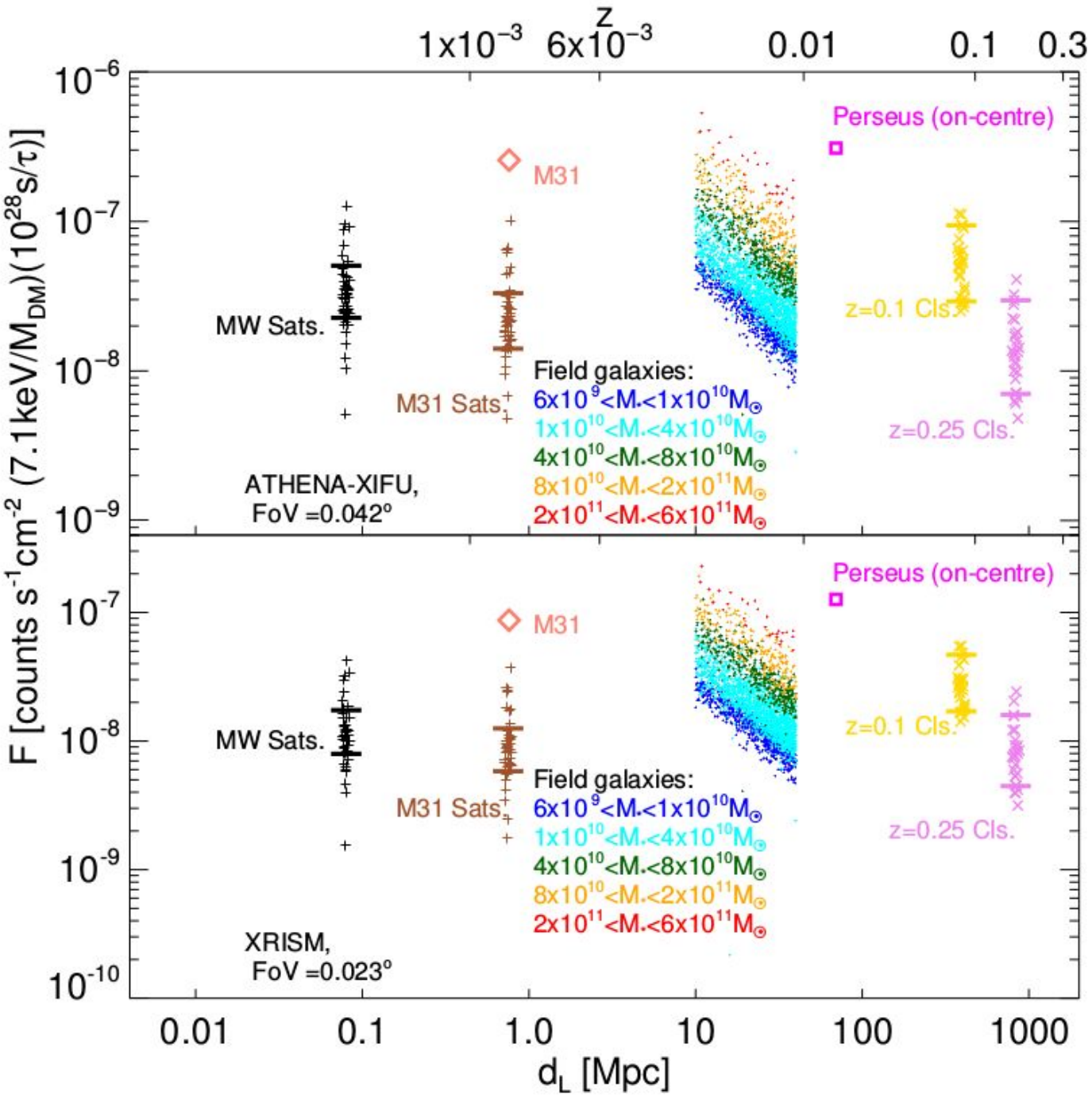
3 instruments specifications:
XMM-Newton: 28' x 28' FoV
XRISM: 3' FoV
ATHENA: *Widel Field Imager* (WFI) 40' x40'
and *X-ray Integral Field Unit* (X-IFU) 5.3'

CDM and WDM X-ray decay fluxes

Local Universe decay fluxes:

ATHENA-WFI (top)

and XRISM (bottom)

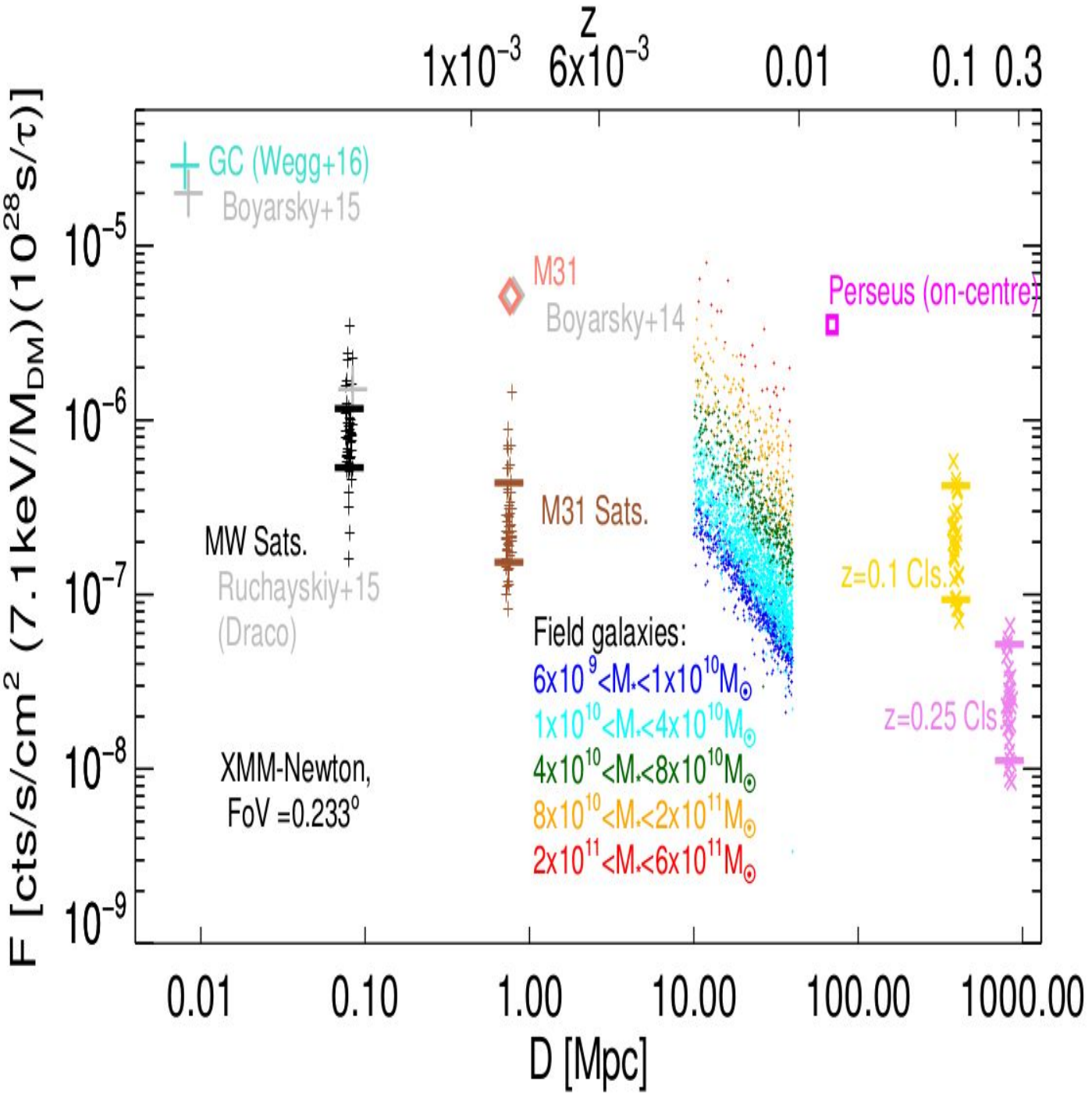


Lovell,...,WH et al., MNRAS'18

CDM and WDM X-ray decay fluxes

Local Universe decay fluxes:

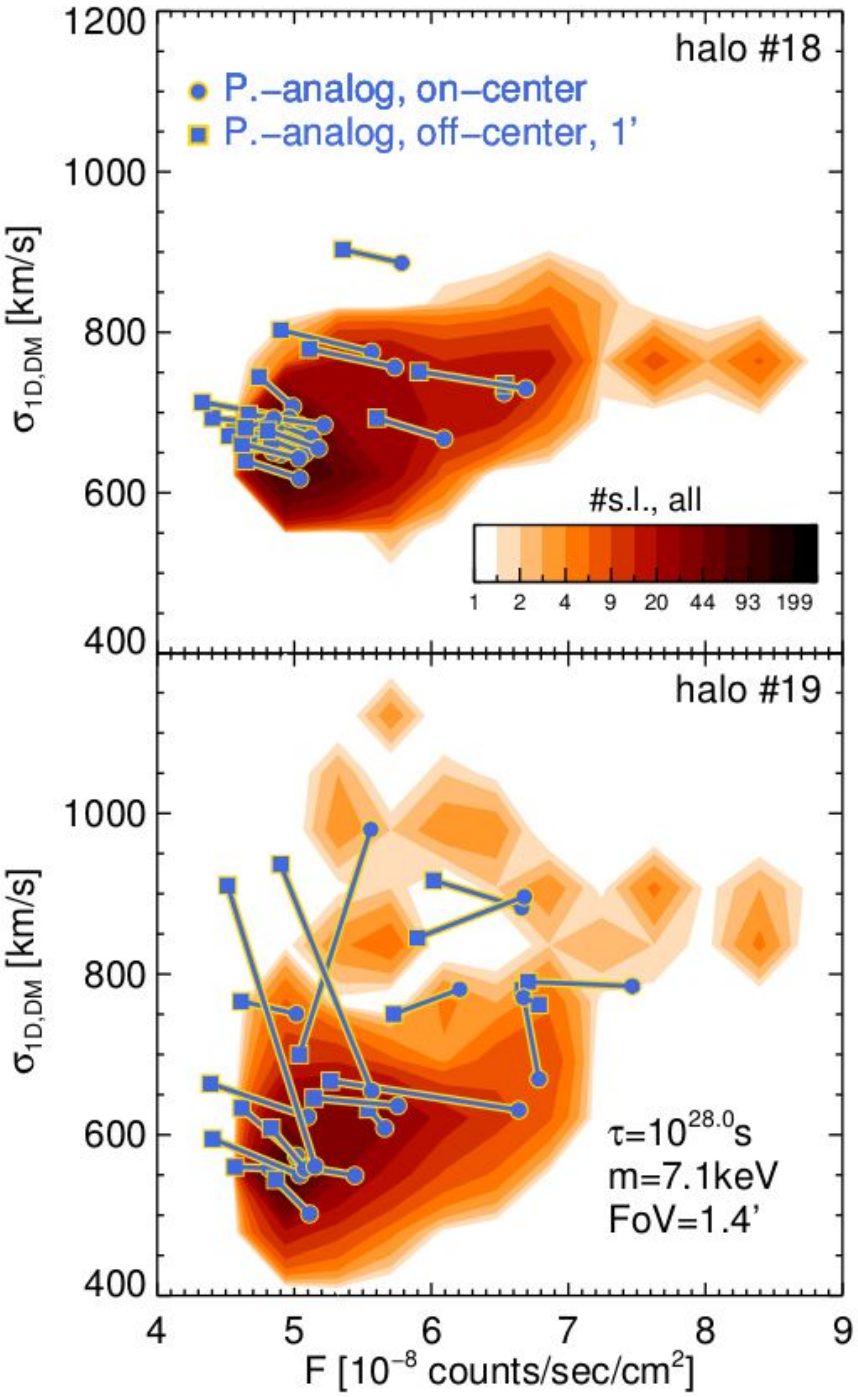
XMM-Newton FoV

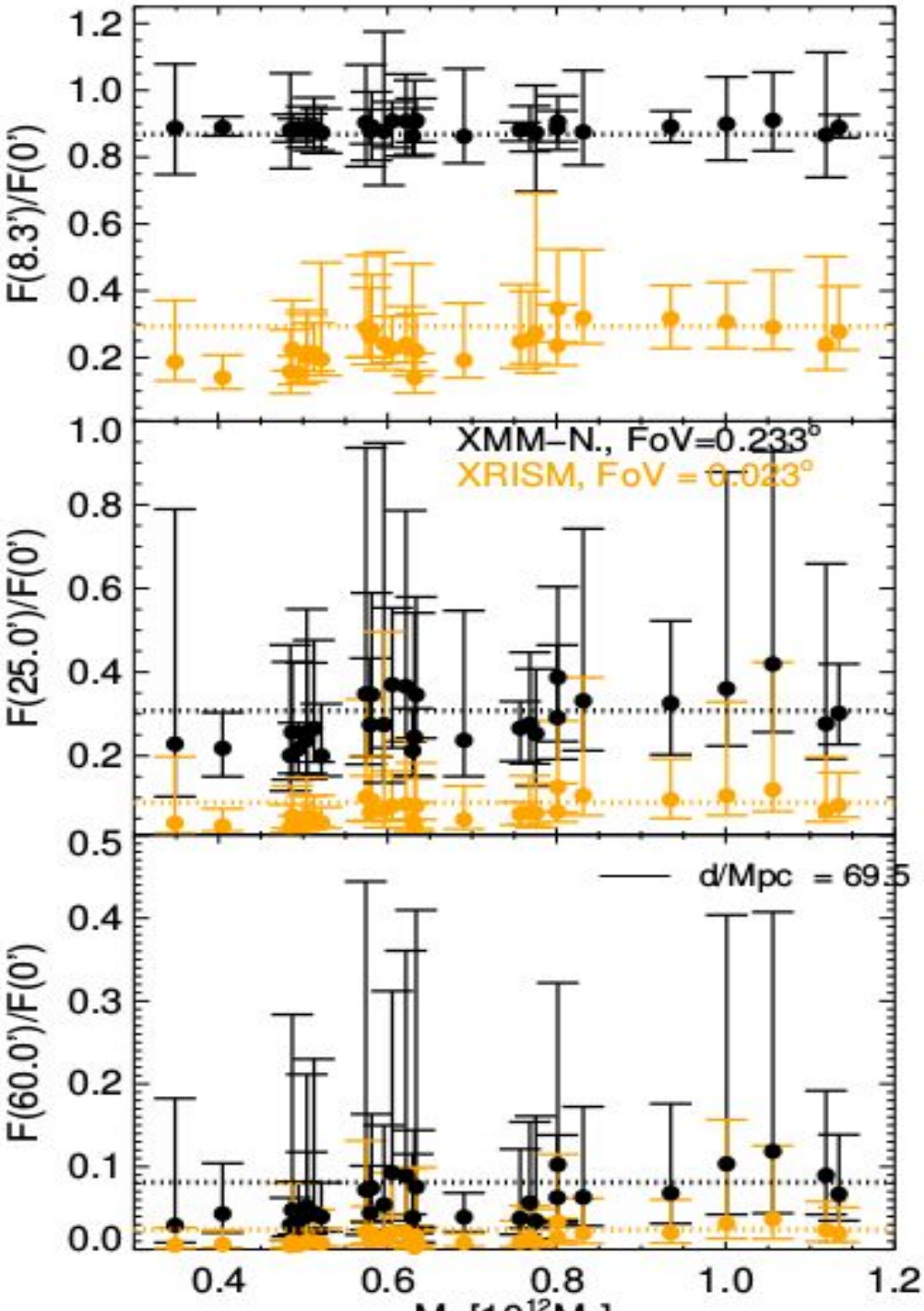


Lovell,...,WH et al., MNRAS'18

Lovell,...,WH et al., ApJ'19

Perseus cluster offset flux ratio





TAKE HOME MESSAGES

- The hunt for DM is on
- The indirect (astrophysical) window for detection
  might be the most promising in the coming decade
- 7.1 keV Sterile neutrino is a viable contendent
- X-ray emission lines from its decay can be observed by future space missions
- Local Universe counts predicted to be $\sim 10^{-5} \div 10^{-7}$ cnts/s/cm^2(normalization)
- 3.5 keV line is Gaussian and Perseus cluster on/off center measurement can provide ~>3σ detection