Angular Power Spectrum of Sterile Neutrino Decay Lines: the Role of eROSITA

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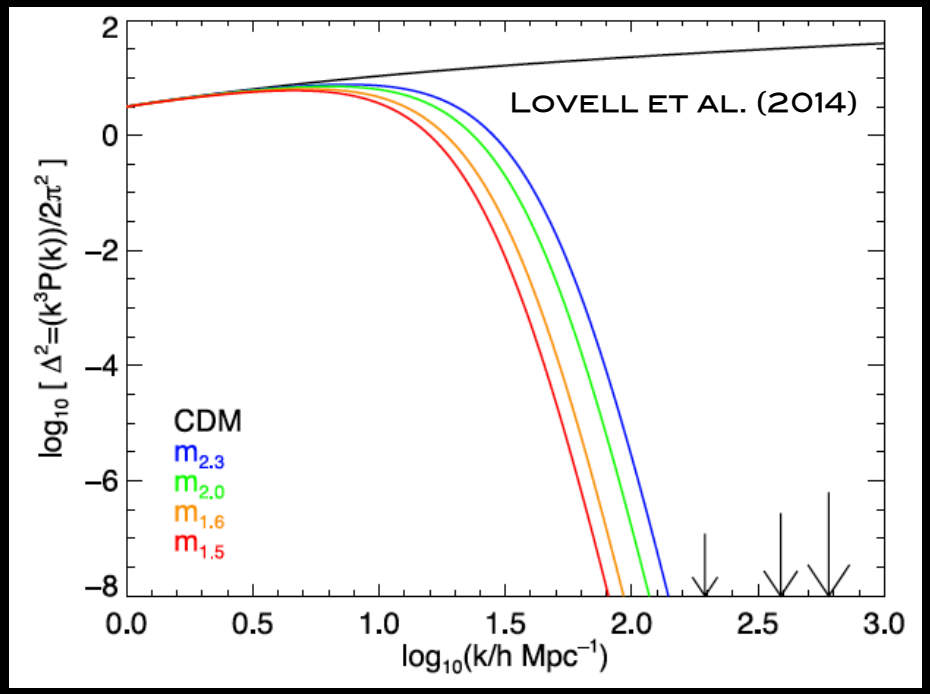
STERILE NEUTRINO DARK MATTER

NEUTRINO MASSES SUGGEST THE EXISTENCE OF RIGHT-HANDED DEGREES OF FREEDOM: THE STERILE NEUTRINOS

INTERESTING WARM(-ISH) DARK MATTER CANDIDATE

- NON-RELATIVISTIC SPEEDS IN THE RADIATION DOMINATED ERA
- MOST CDM SUCCESSES EXTENDED TO WDM MODELS
- DIFFERENCES AT SMALL SCALES: SUPPRESSION OF SMALL SCALE STRUCTURES

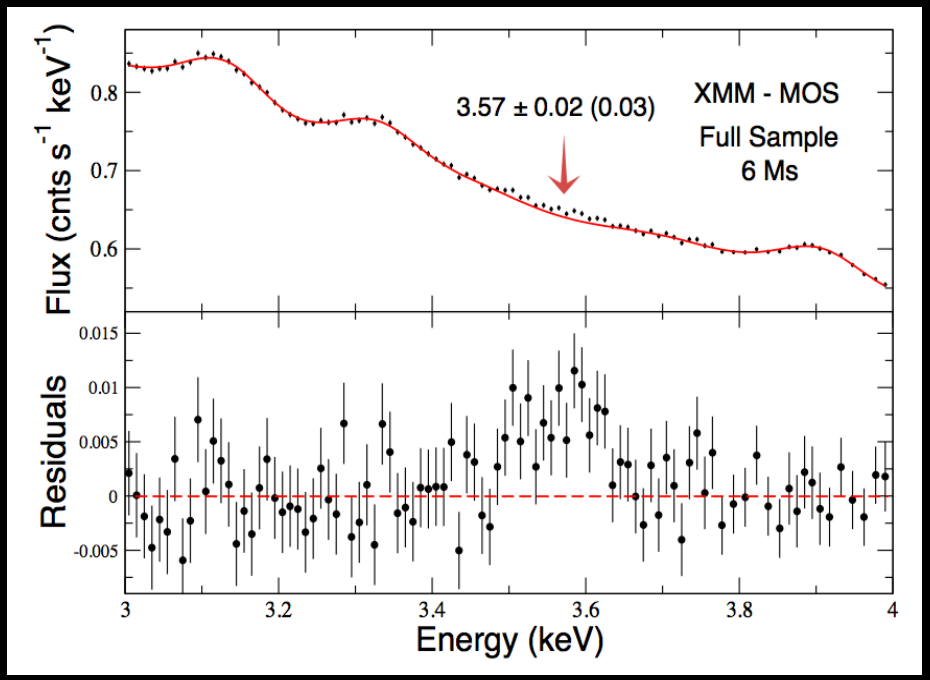


SEE, E.G., DODELSON & WIDROW (1994); SHI & FULLER (1999); BOYARSKY, RUCHAYSKIY & SHAPOSHNIKOV (2009); BOYARSKY ET AL. (2009); KUSENKO (2009) – A. PALAZZO (WED) + STERILE NEUTRINO SESSION (THU)

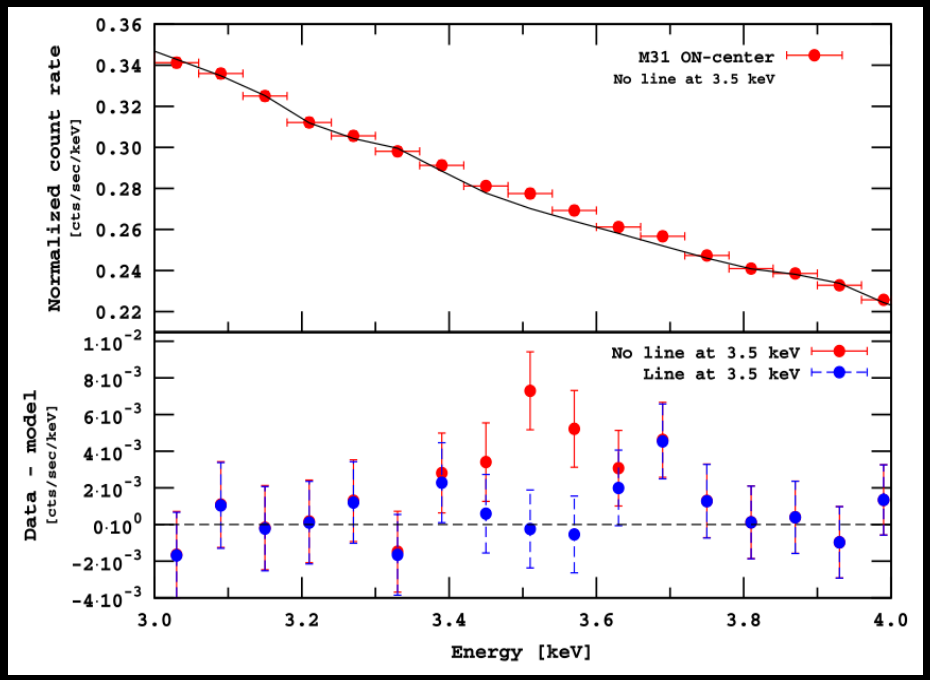
STERILE NEUTRINO DECAYS

$$\nu_s \to \gamma\nu \longrightarrow \Gamma_{\nu_s} \simeq (7.2 \times 10^{29}\ \mathrm{s})^{-1} \left(\frac{\sin^2 2\theta}{10^{-8}}\right) \left(\frac{m_{\nu_s}}{1\ \mathrm{keV}}\right)^5$$

⟶ CLAIMED LINE FEATURE IN X-RAYS!

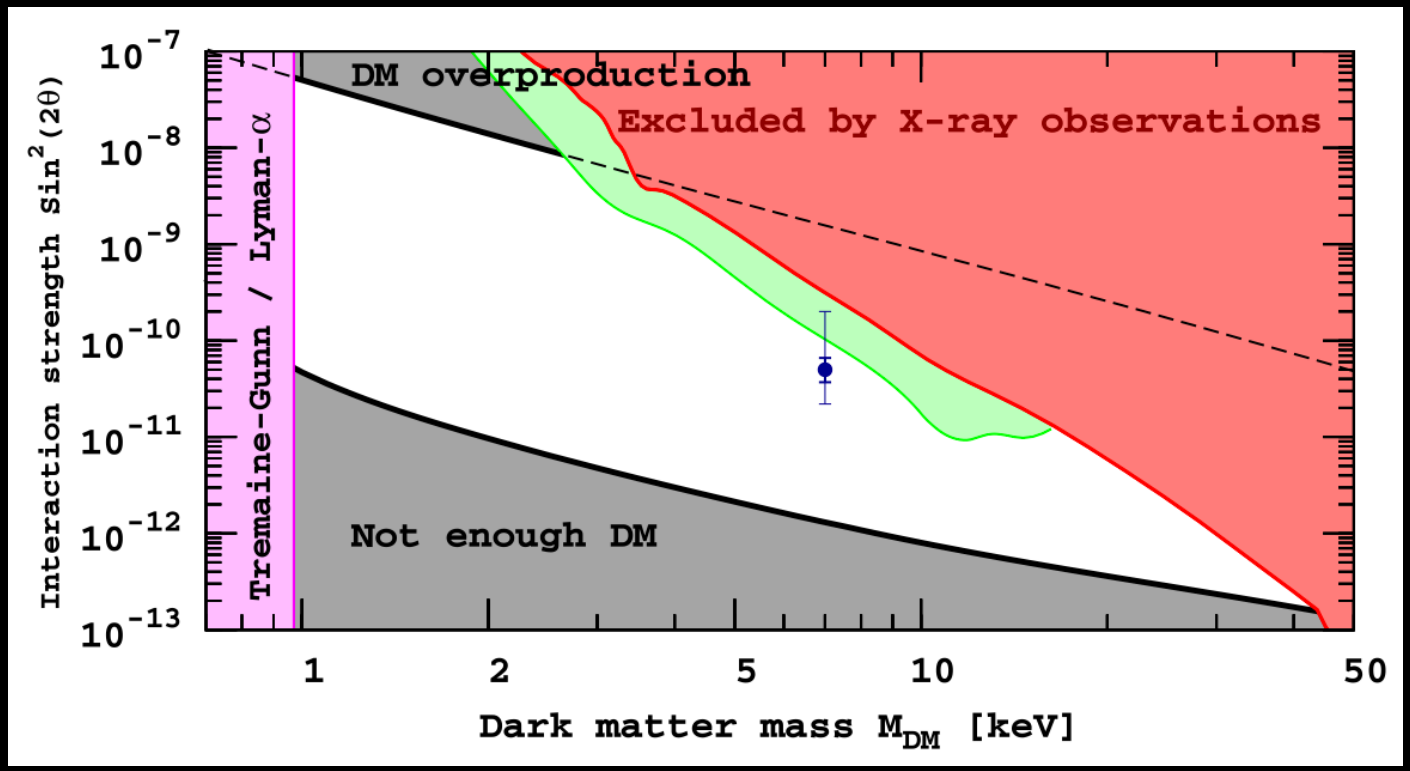


BULBUL ET AL. (2014A)



BOYARSKY ET AL. (2014A)

STERILE NEUTRINO DECAYS



Boyarsky et al. (2014a)

3.5-keV line is debated...

Confirm: Boyarsky et al. (2014b,c); Bulbul et al. (2014b); Iakubovski et al. (2015) – Talk by J. Franse (wed)

Do Not Confirm: Malyshev et al. (2014); Anderson et al. (2014); Urban et al. (2014); Jeltema & Profumo (2015); Carlson et al. (2015); Tamura et al. (2015)

A DIFFERENT APPROACH

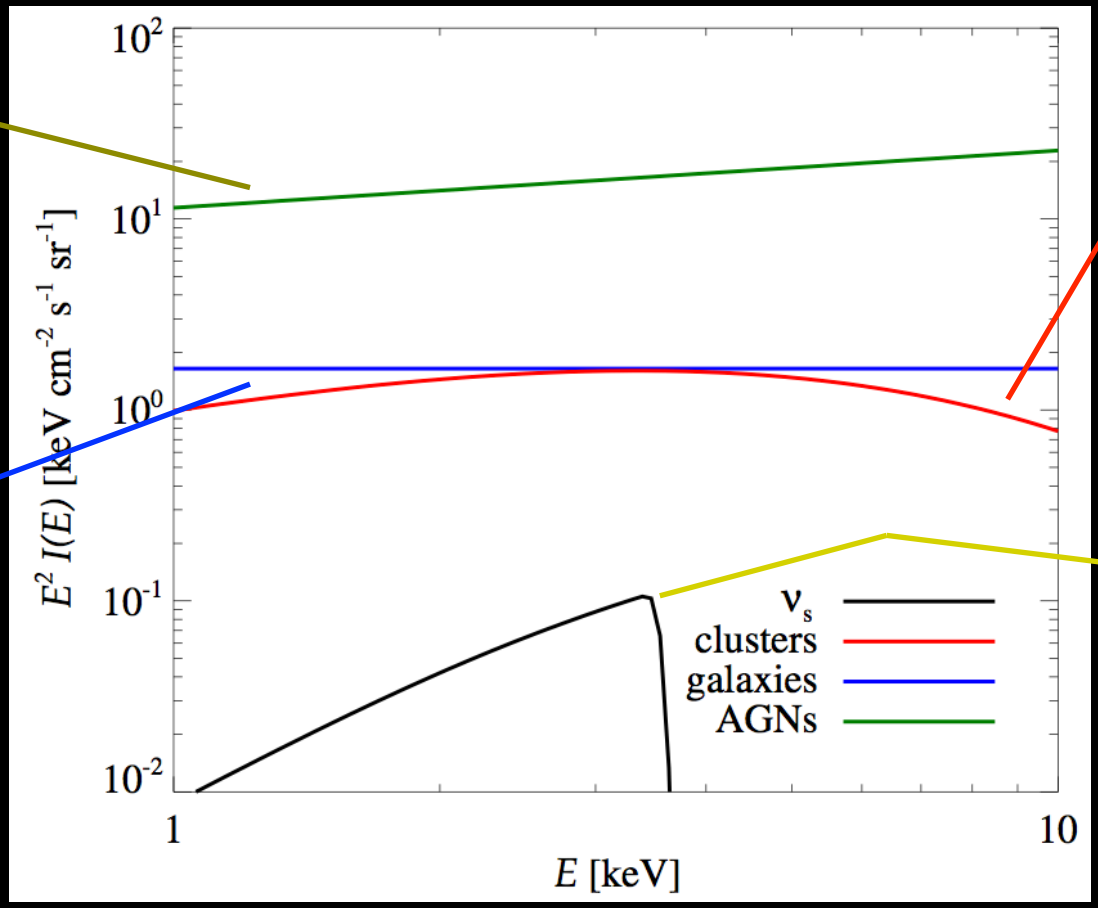
Sterile neutrino decays should contribute to the observed Cosmic X-ray Background (CXB)

Unresolved AGNs
give the main contribution

[luminosity and density evolution model by Aird et al. (2010)]

Unresolved galaxies
powered by X-ray binaries

[luminosity function model by Ptak et al. (2007)]



Thermal bremsstrahlung emission from **Resolved & unresolved clusters of galaxies**

[mass function + phenomenological model by FZ, Pfrommer & Prada (2014)]

Sterile neutrino decays from all structures in the Universe

[mass function + NFW DM profile + Bulbul et al./ Boyarsky et al. sterile neutrino]

FZ, Weniger & Ando (2015)

ANGULAR POWER SPECTRUM

$$C_\ell \equiv \langle |a_{\ell m}|^2 \rangle$$

CXB INTENSITY ANGULAR POWER SPECTRUM AT MULTIPOLE L

$$\theta = \pi/\ell$$

$$a_{\ell m} = \int d\Omega_{\boldsymbol{n}}\, I(\boldsymbol{n})\, Y^*_{\ell m}(\boldsymbol{n})$$

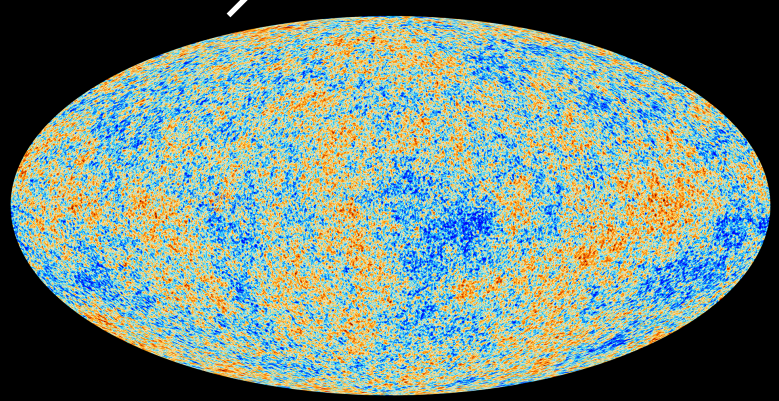
INTENSITY FLUCTUATIONS

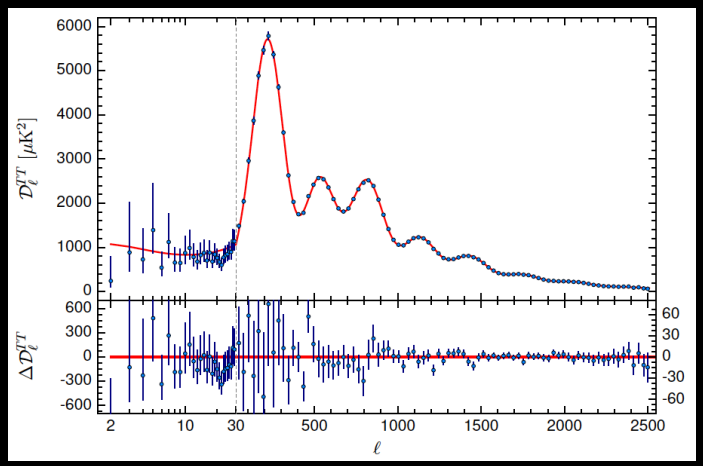
SPHERICAL HARMONICS

SIMILARLY TO THE CMB TEMPERATURE ΔT POWER SPECTRUM

$$a_{lm} = \int d\Omega_{\mathbf{n}}\, \Delta T(\mathbf{n}) Y^*_{lm}(\mathbf{n})$$

$D_l = C_l\, l\, (l+1) / 2\pi$





ANGULAR POWER SPECTRUM

FZ, Weniger & Ando (2015)

$$C_\ell^A(E) = \int_0^\infty \frac{d\chi}{\chi^2}\, W_A([1+z]E, z)^2\; P_A\left(k = \frac{\ell}{\chi}, z\right)$$

WINDOW FUNCTION FOR A = AGNs, GALAXIES, CLUSTERS OR STERILE NEUTRINOS

$$W_{\nu_s}(E,z) = \frac{\Omega_{\rm dm}\rho_c\Gamma_{\nu_s}}{2(2\pi)^{3/2}m_{\nu_s}(1+z)\sigma_E}\exp\left[-\frac{(E-m_{\nu_s}/2)^2}{2(1+z)^2\sigma_E^2}\right]$$

POWER SPECTRUM OF SOURCE A USING HALO MODEL

STERILE NEUTRINOS

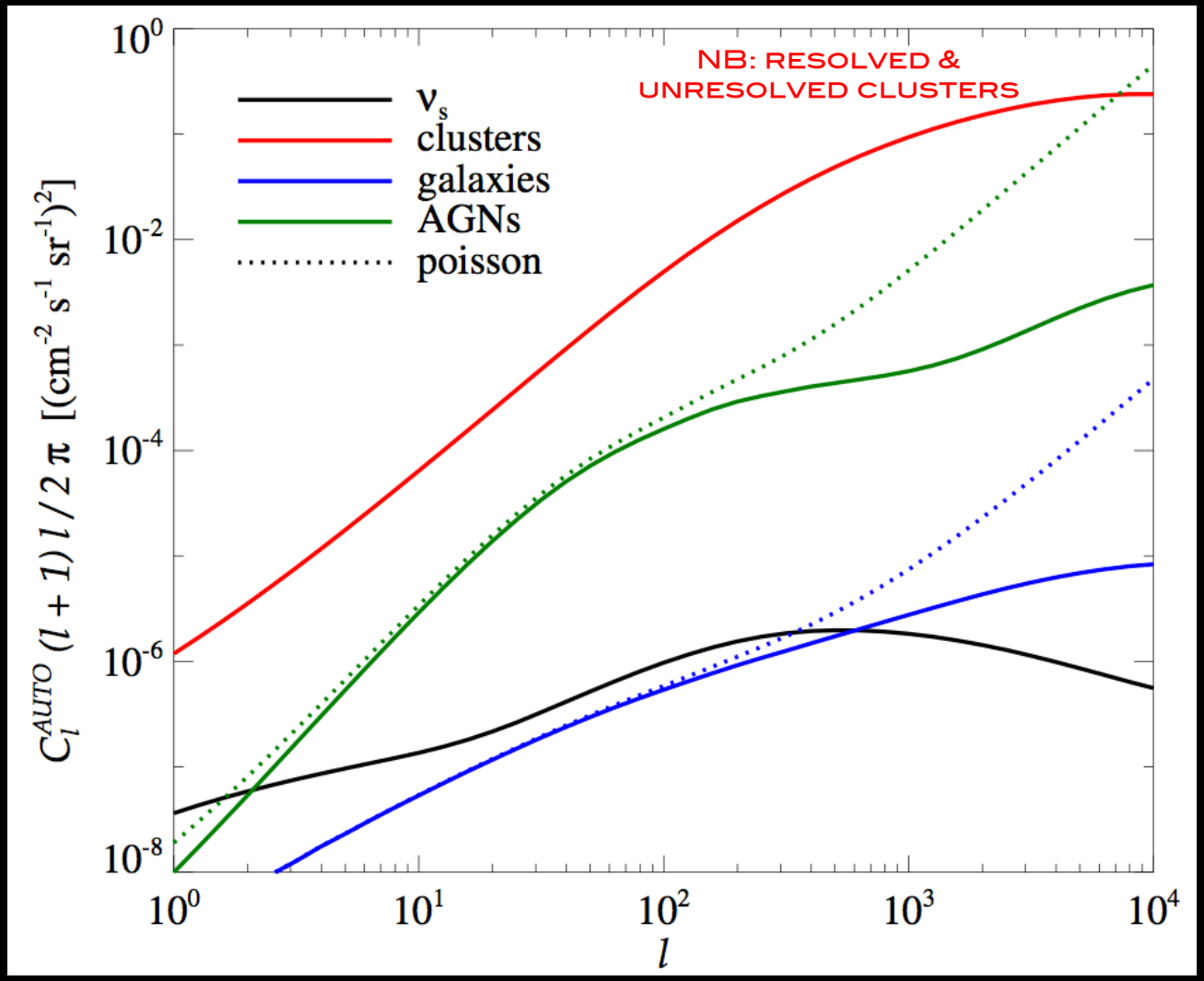
$$P_\delta^{1h} = \left(\frac{1}{\Omega_{\rm dm}\rho_c}\right)^2 \int dM_{200}\frac{dn}{dM_{200}}\left[\int 4\pi r^2 dr\,\rho_{\rm dm}(r)\frac{\sin(kr)}{kr}\right]^2$$

$$P_\delta^{2h} = \left[\left(\frac{1}{\Omega_{\rm dm}\rho_c}\right)\int dM_{200}\frac{dn}{dM_{200}}\,b(M_{200},z)\int 4\pi r^2 dr\,\rho_{\rm dm}(r)\frac{\sin(kr)}{kr}\right]^2 P_{\rm lin}(k,\chi)$$

See, e.g., Cooray & Seth (2002); Ando et al. (2007); Fornasa et al. (2012); Ando (2014); Fornengo & Regis (2014) – Talks by M. Fornasa (Mon) and S. Ando (Wed)

ANGULAR POWER SPECTRUM

3.4 – 3.6 KEV



FZ, Weniger & Ando (2015)

ANGULAR POWER SPECTRUM

Auto-correlation power spectrum:

$$C_\ell^A(E) = \int_0^\infty \frac{d\chi}{\chi^2}\, W_A([1+z]E, z)^2\, P_A\left(k = \frac{\ell}{\chi}, z\right)$$

Cross-correlation power spectrum:

$$C_\ell^{\mathrm{A,B}}(E) = \int \frac{d\chi}{\chi^2} W_{\mathrm{A}}([1+z]E, z) W_{\mathrm{B}}(\chi) P_{\mathrm{A,B}}\left(k = \frac{\ell}{\chi}, \chi\right)$$

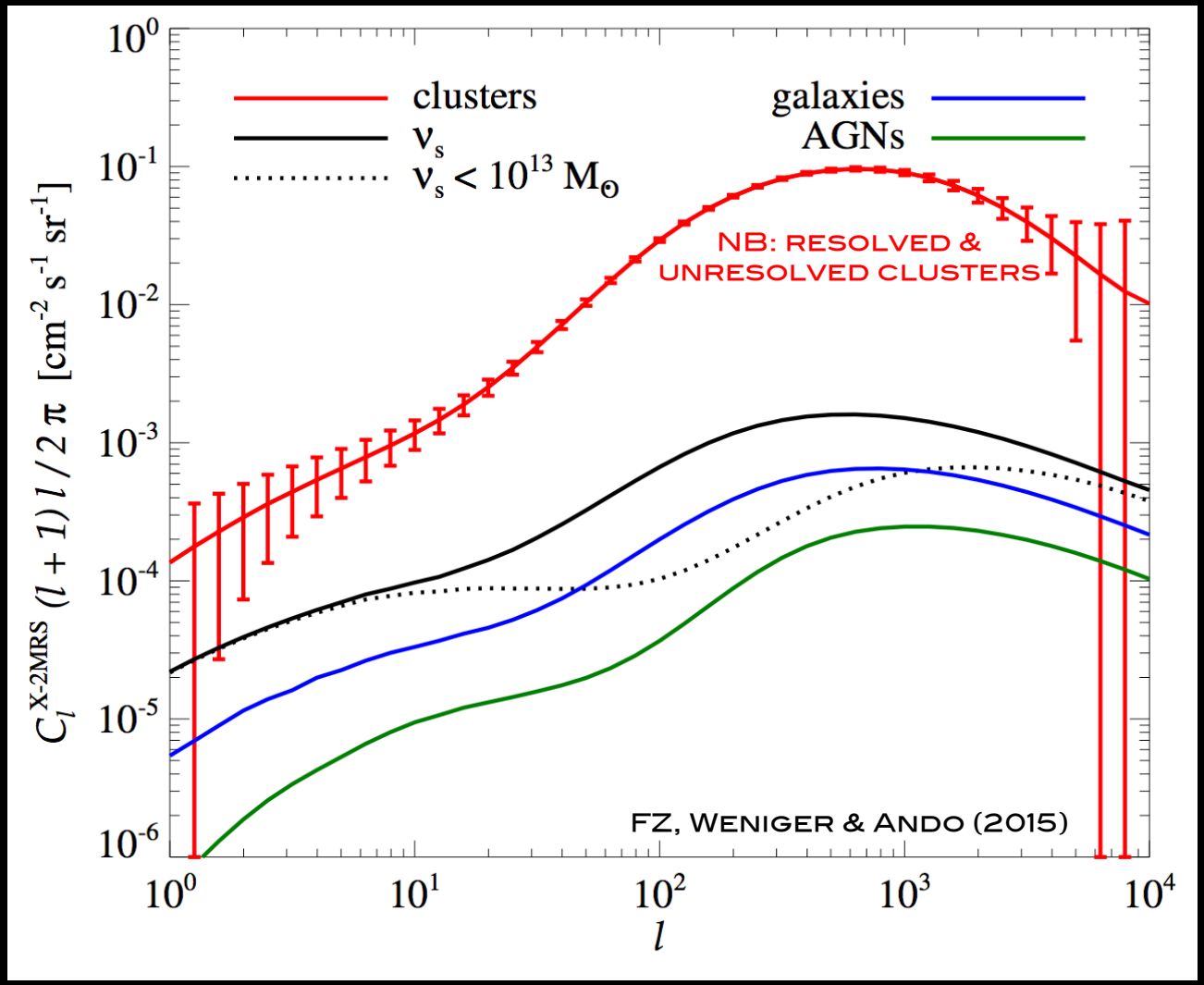
Idea is to correlate with a tracer (B) of the dark matter distribution to highlight the possible sterile neutrino decays

See, e.g., Camera et al. (2013, 2014); Fornengo & Regis (2014); Ando et al. (2014); Ando (2014); Shirasaki et al. (2014); Fornengo et al. (2015); Xia et al. (2015); Cuoco et al. (2015); Fornasa & Sanchez-Conde (2015)

Talks by J.Q. Xia (mon), S. Camera (mon) and A. Cuoco (tue)

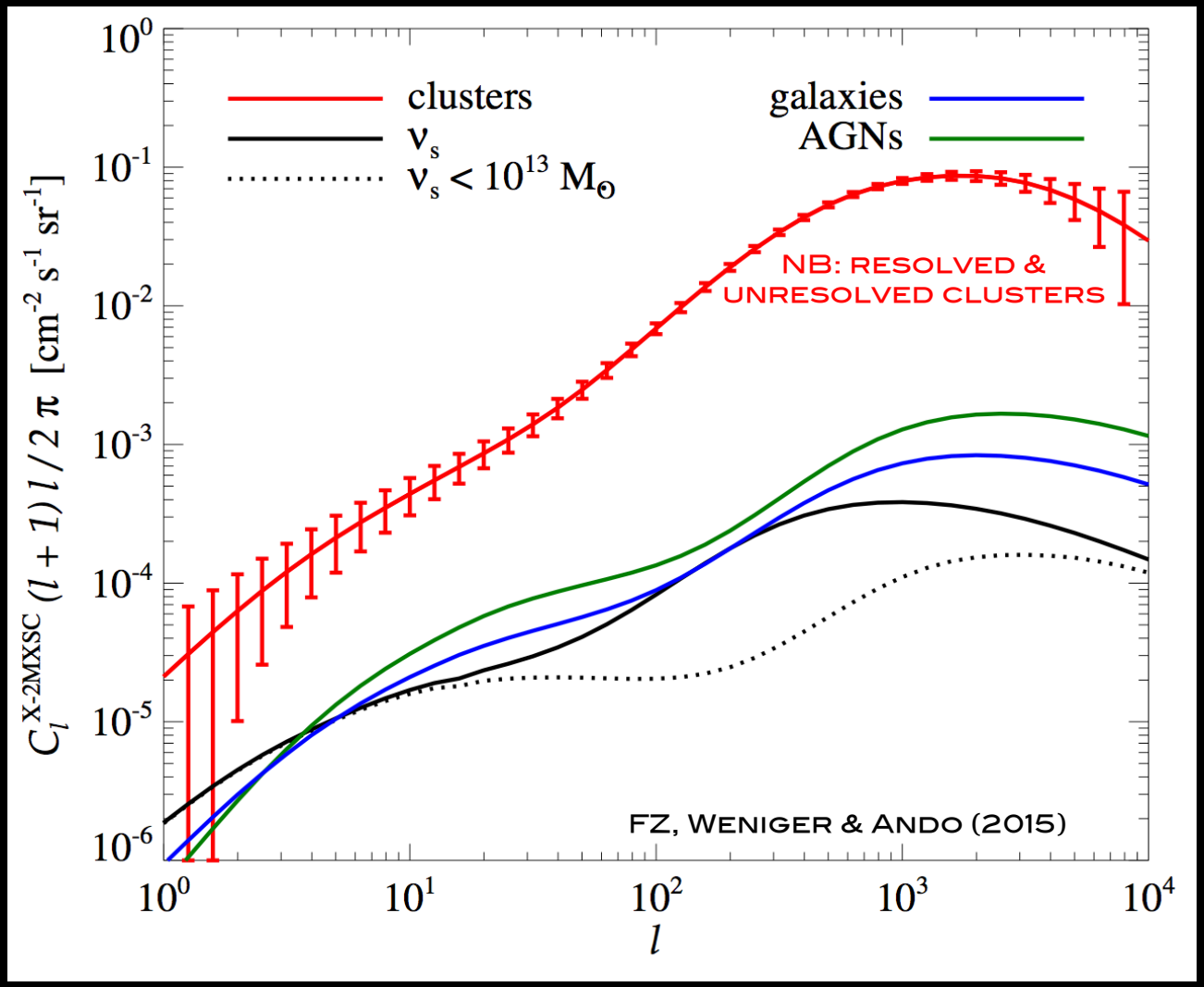
CROSS-CORRELATION WITH 2MASS – 2MRS

3.4 – 3.6 KEV



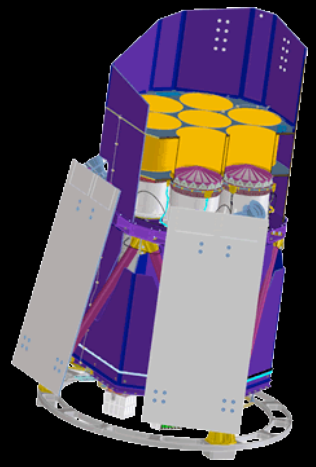
CROSS-CORRELATION WITH 2MASS – 2MXSC

3.4 – 3.6 KEV

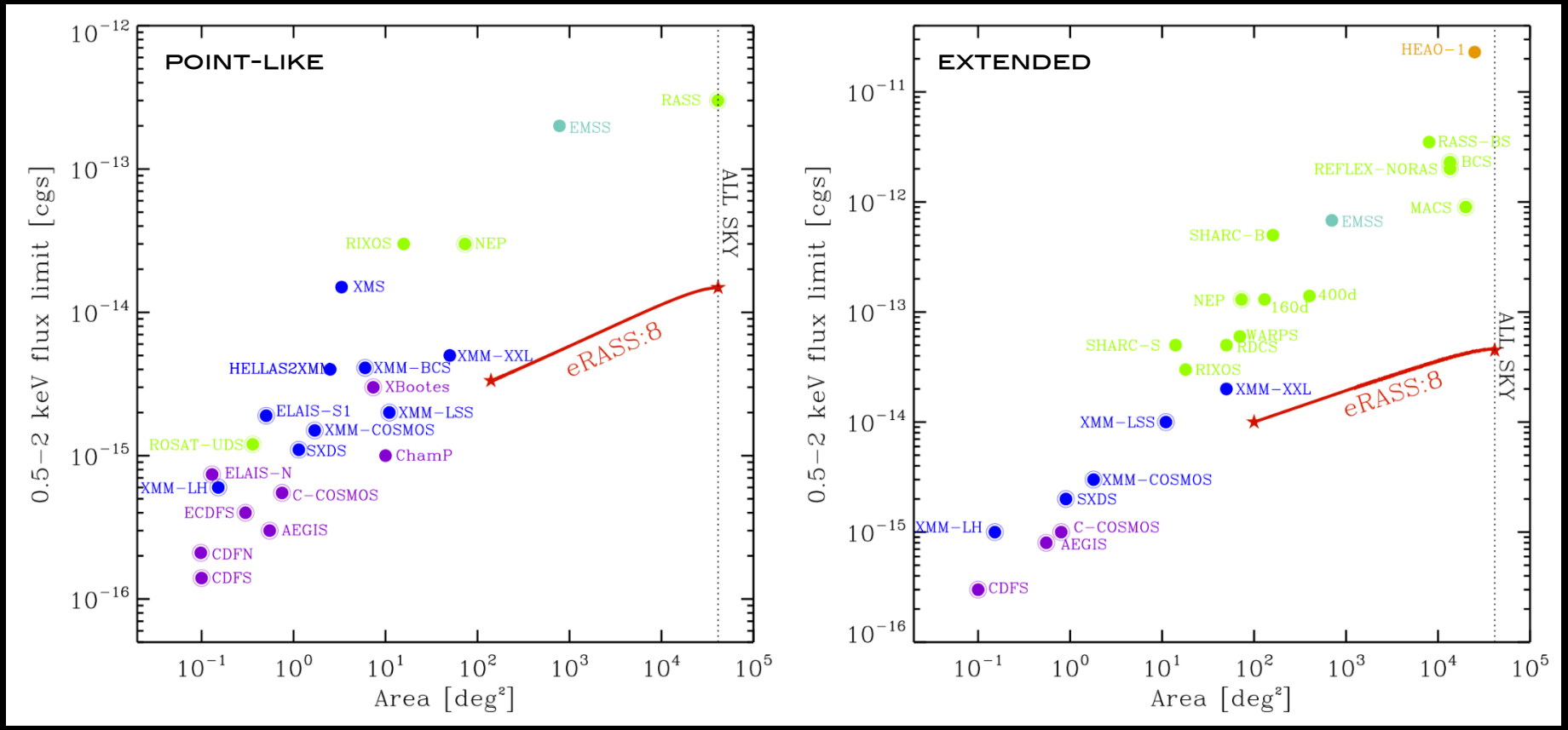


eROSITA ALL-SKY SURVEY

eROSITA IS THE PRIMARY INSTRUMENT ON THE RUSSIAN SPEKTRUM-ROENTGEN-GAMMA (SRG) MISSION WITH LAUNCH IN 2017

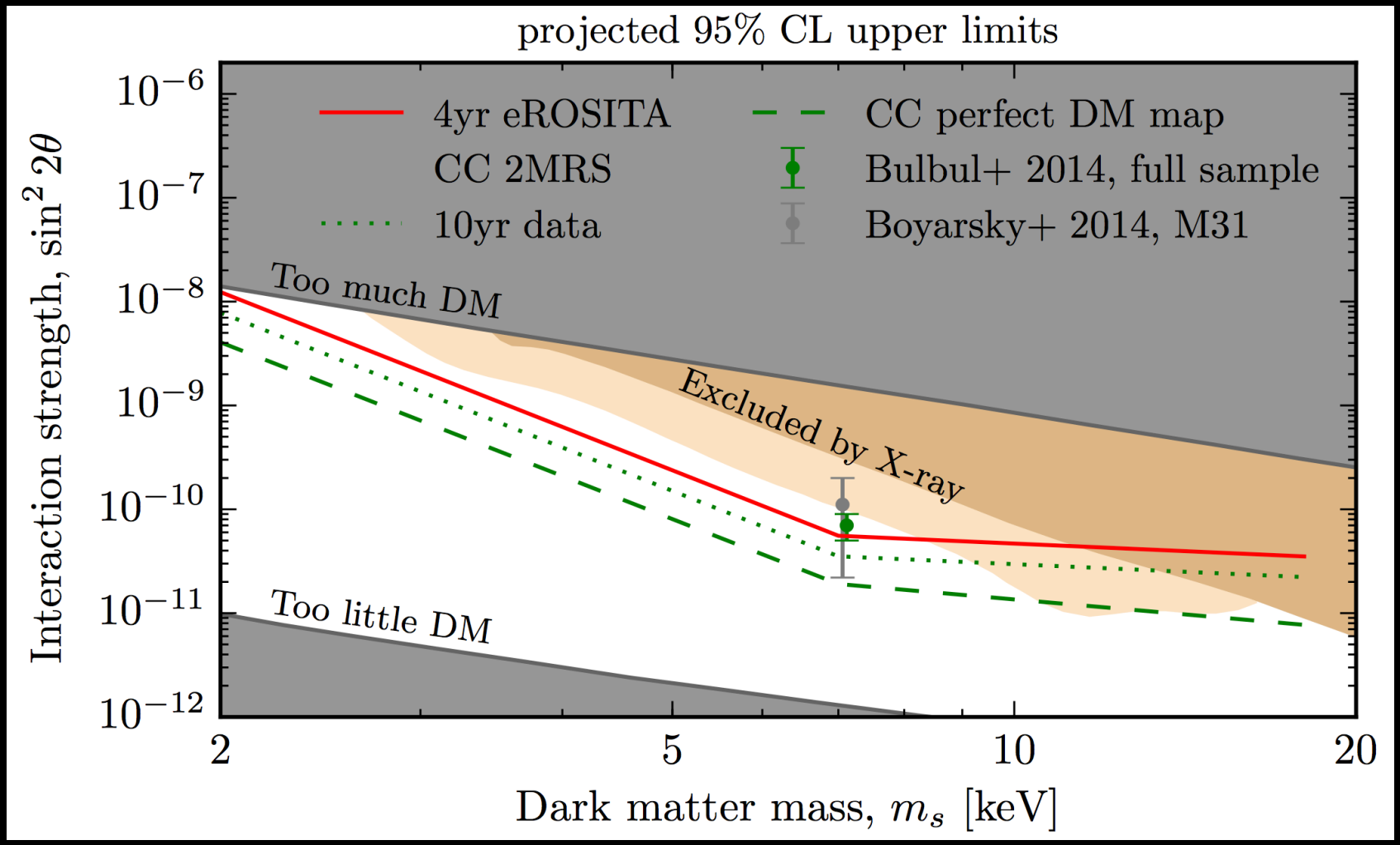


MERLONI ET AL. (2012)



PROJECTED LIMITS FOR eROSITA

NB: 3 ENERGY-BIN SIDE-BAND ANALYSIS



FZ, Weniger & Ando (2015)

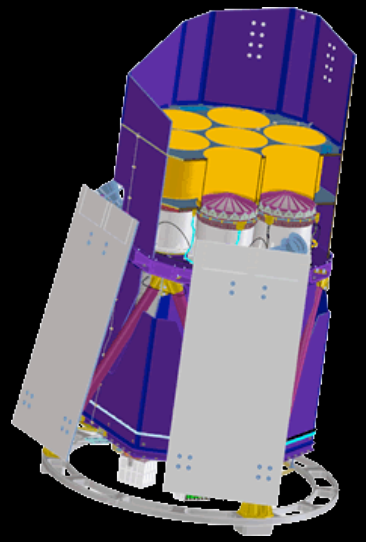
SUMMARY AND PROSPECTS

3.5-keV line could be due to sterile neutrino decays, but interpretation is debated

Alternative approach: look at anisotropy power spectrum of Cosmic X-ray Background

Sterile neutrino decays are subdominant in auto-correlation but can be highlighted cross-correlating with DM tracers

eROSITA can test this scenario, but E > 10 keV limited by instrumental background + constraining power limited by shot-noise of galaxy catalogues



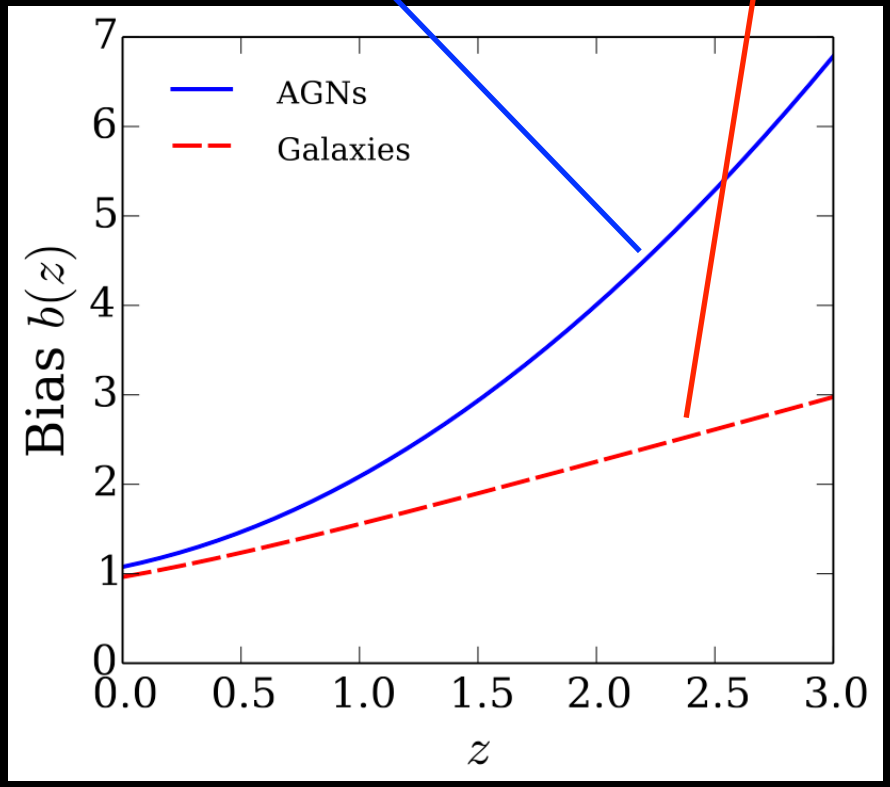
BACK-UP SLIDES

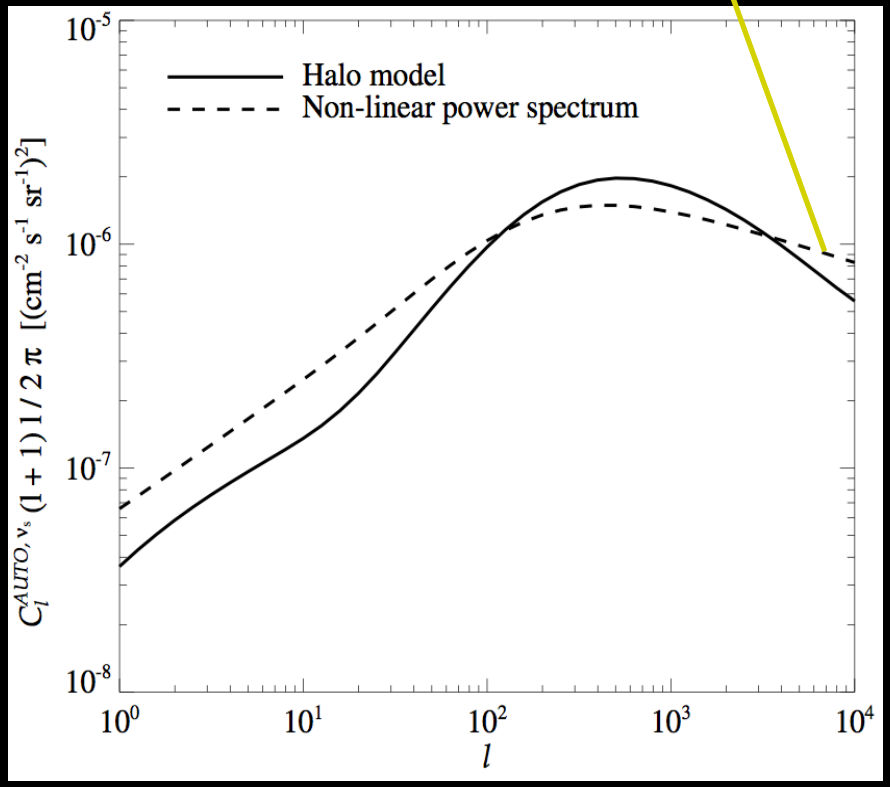
BIAS AND HALO MODEL

ALLEVATO ET AL. (2011)

CAPPELLUTI ET AL. (2012)

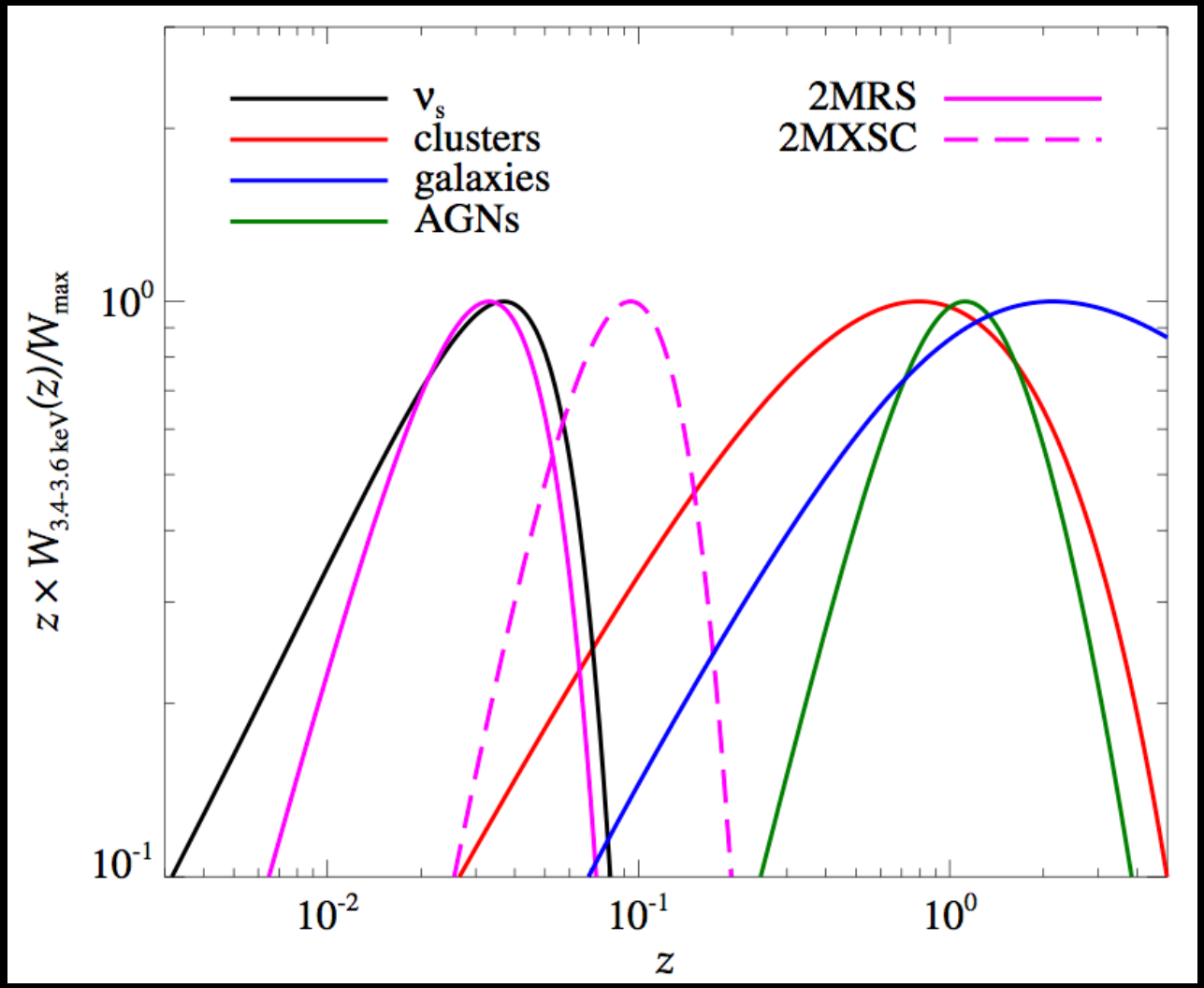
FROM CAMB





FZ, WENIGER & ANDO (2015)

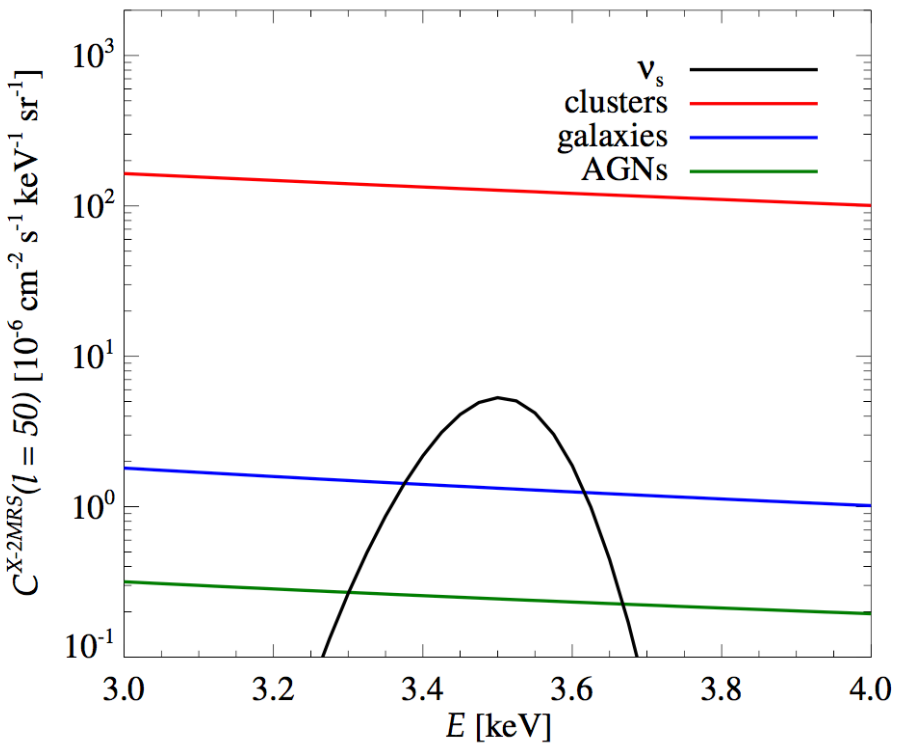
WINDOW FUNCTIONS

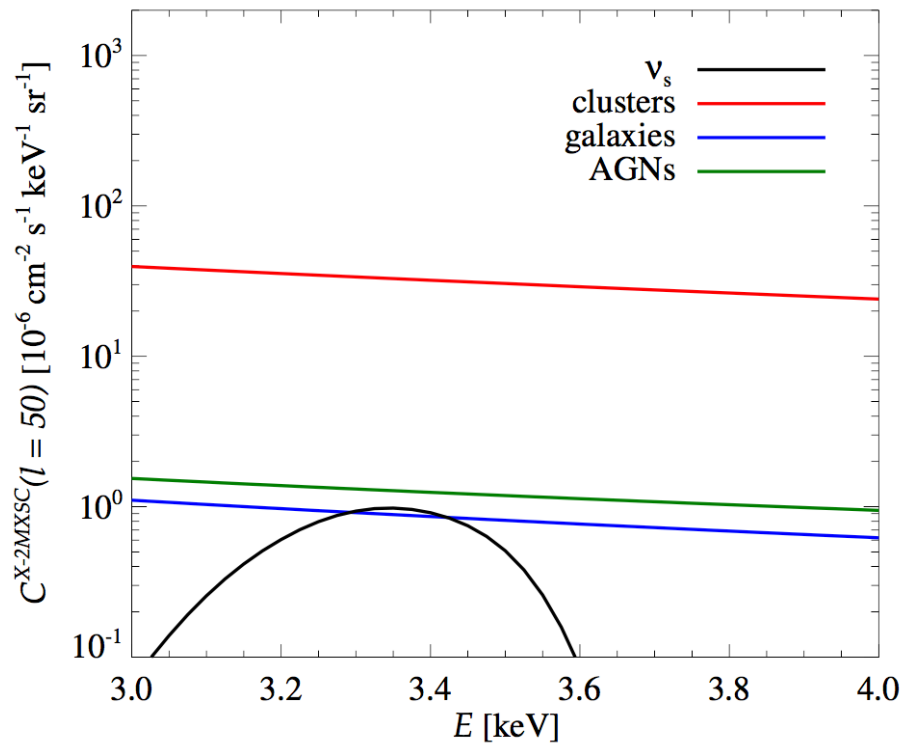


FZ, Weniger & Ando (2015)

CROSS POWER SPECTRUM

AT A GIVEN MULTIPOLE L = 50
FOR 2MRS AND 2MXSC

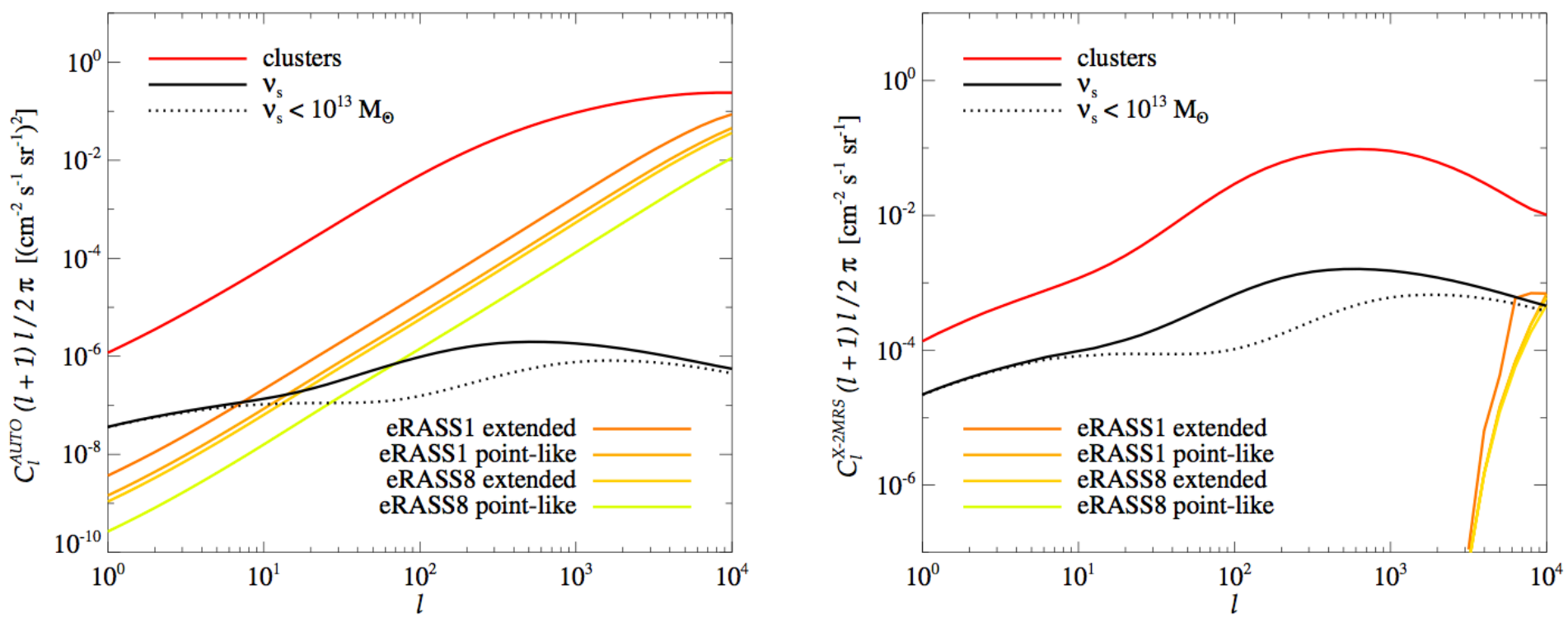




FZ, WENIGER & ANDO (2015)

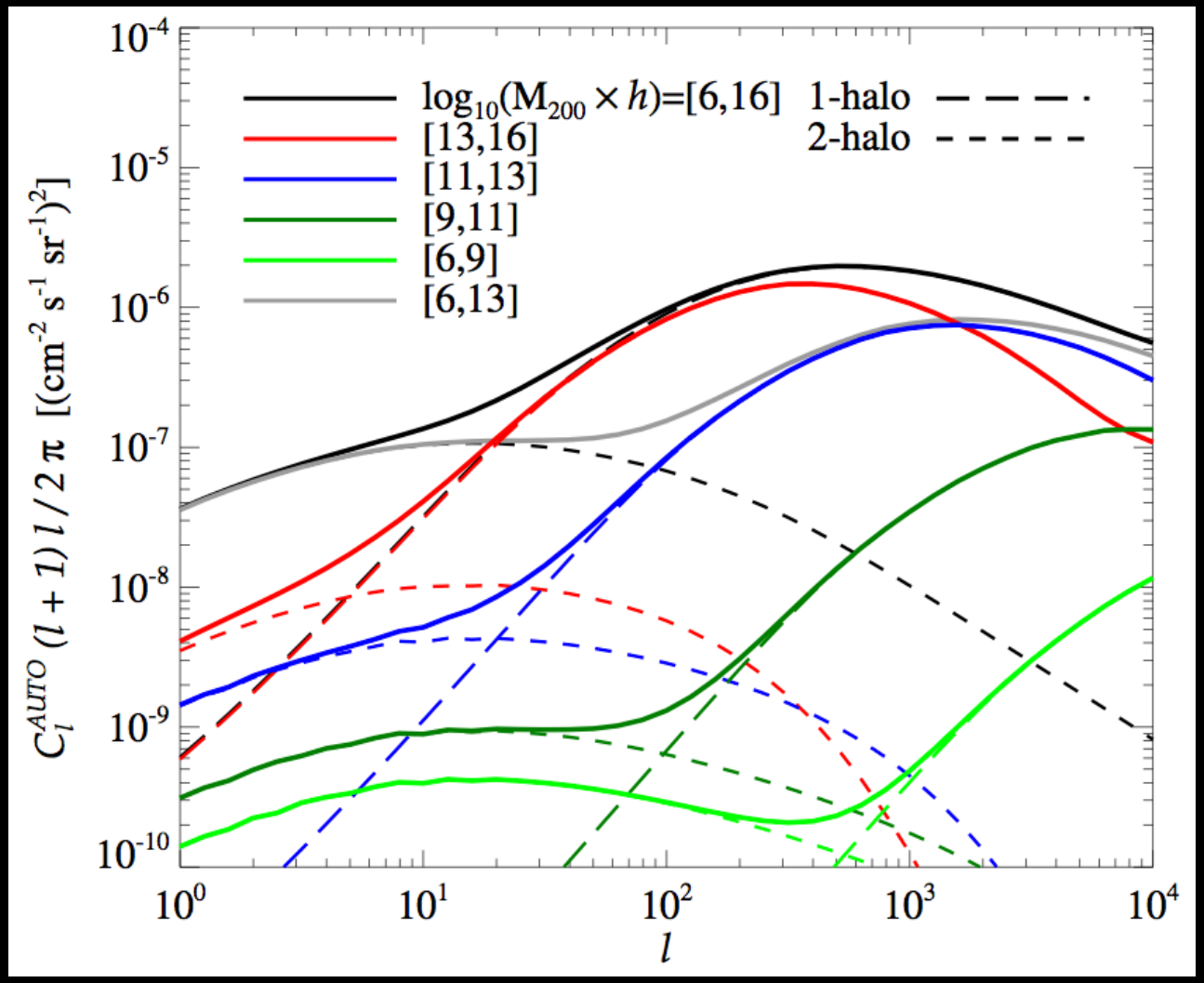
EXCLUDING CLUSTERS

eROSITA SHOULD DE ABLE TO DETECT ALL CLUSTERS OF GALAXIES > 10^{14} $M_\odot$



FZ, Weniger & Ando (2015)

STERILE NEUTRINO IN MASS BINS



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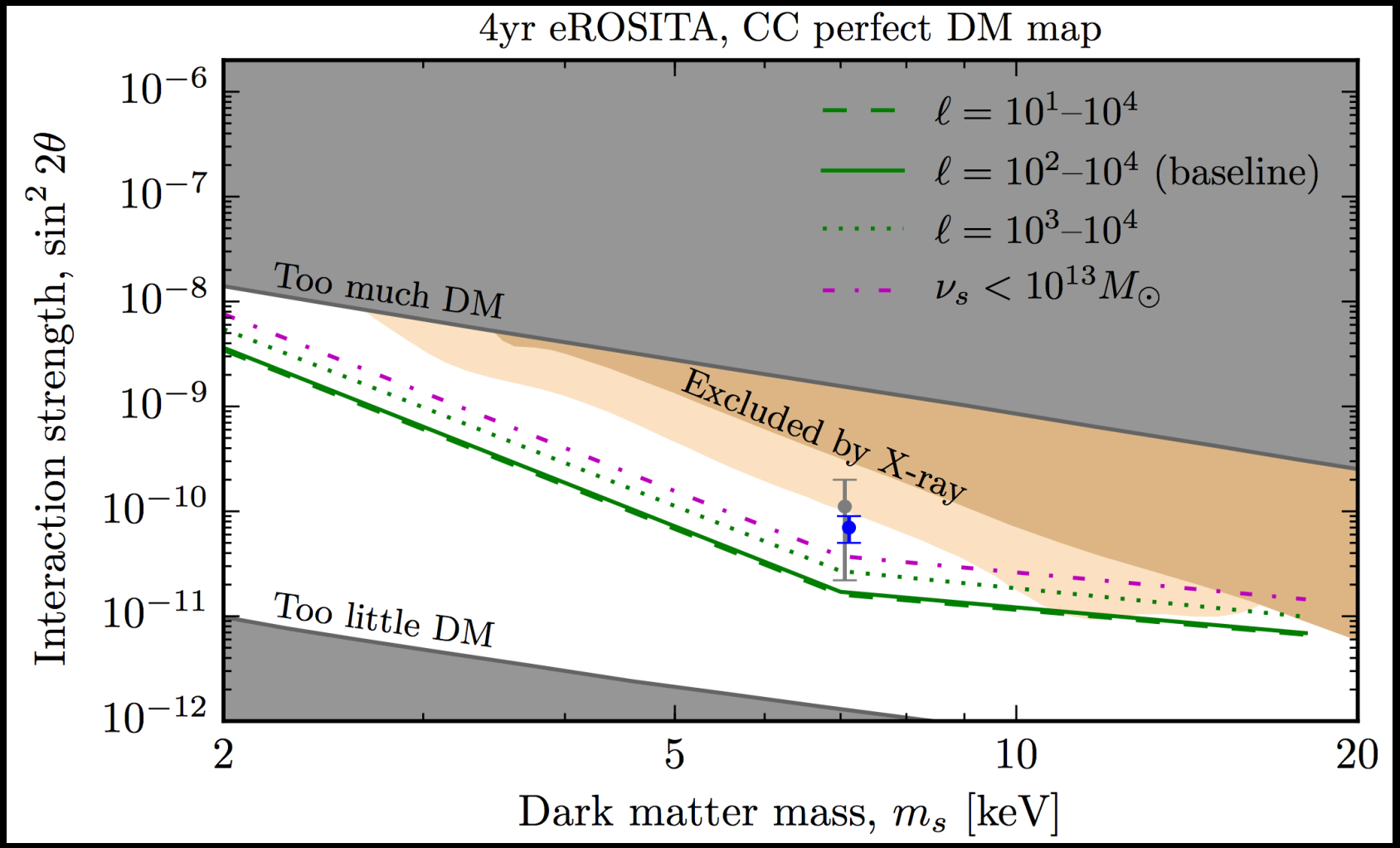
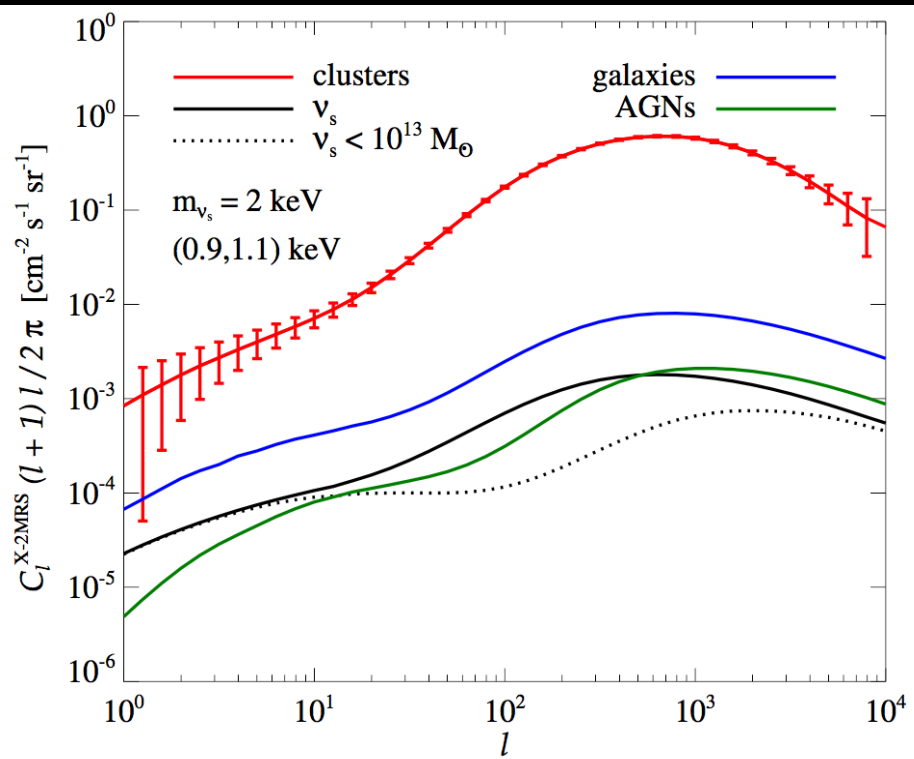


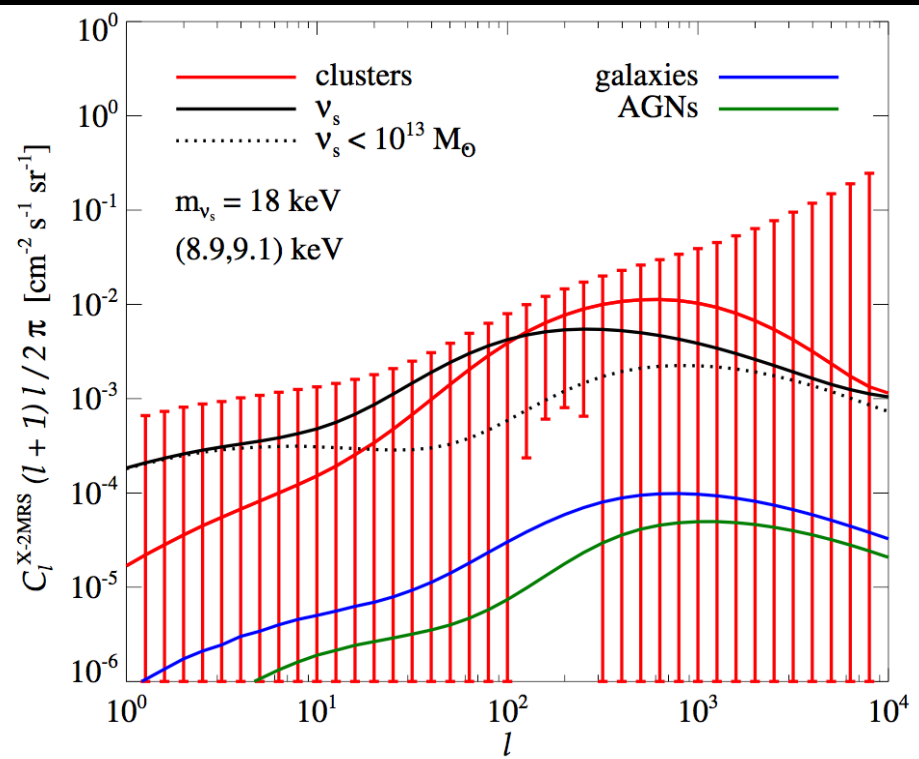
FZ, Weniger & Ando (2015)

CROSS-CORRELATION WITH 2MASS – 2MRS

0.9 – 1.1 KEV



8.9 – 9.1 KEV



FZ, Weniger & Ando (2015)