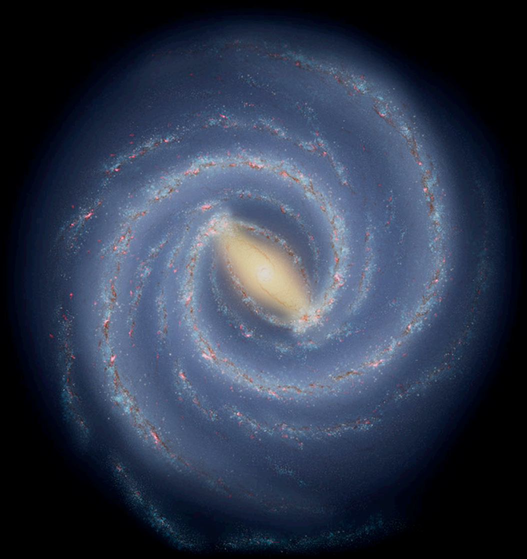
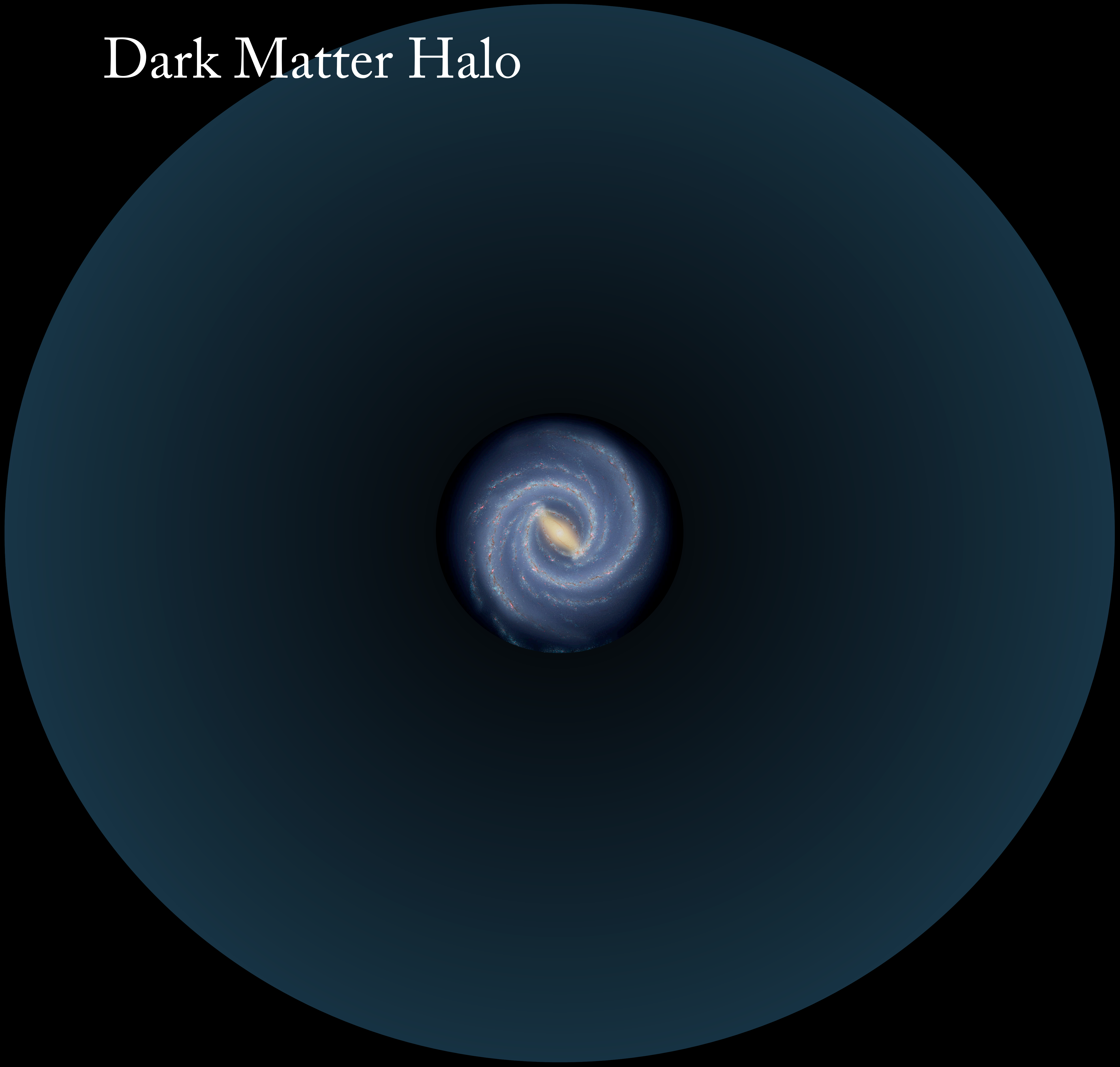
Blazar Boosted Dark Matter

Laura Manenti
The University of Sydney

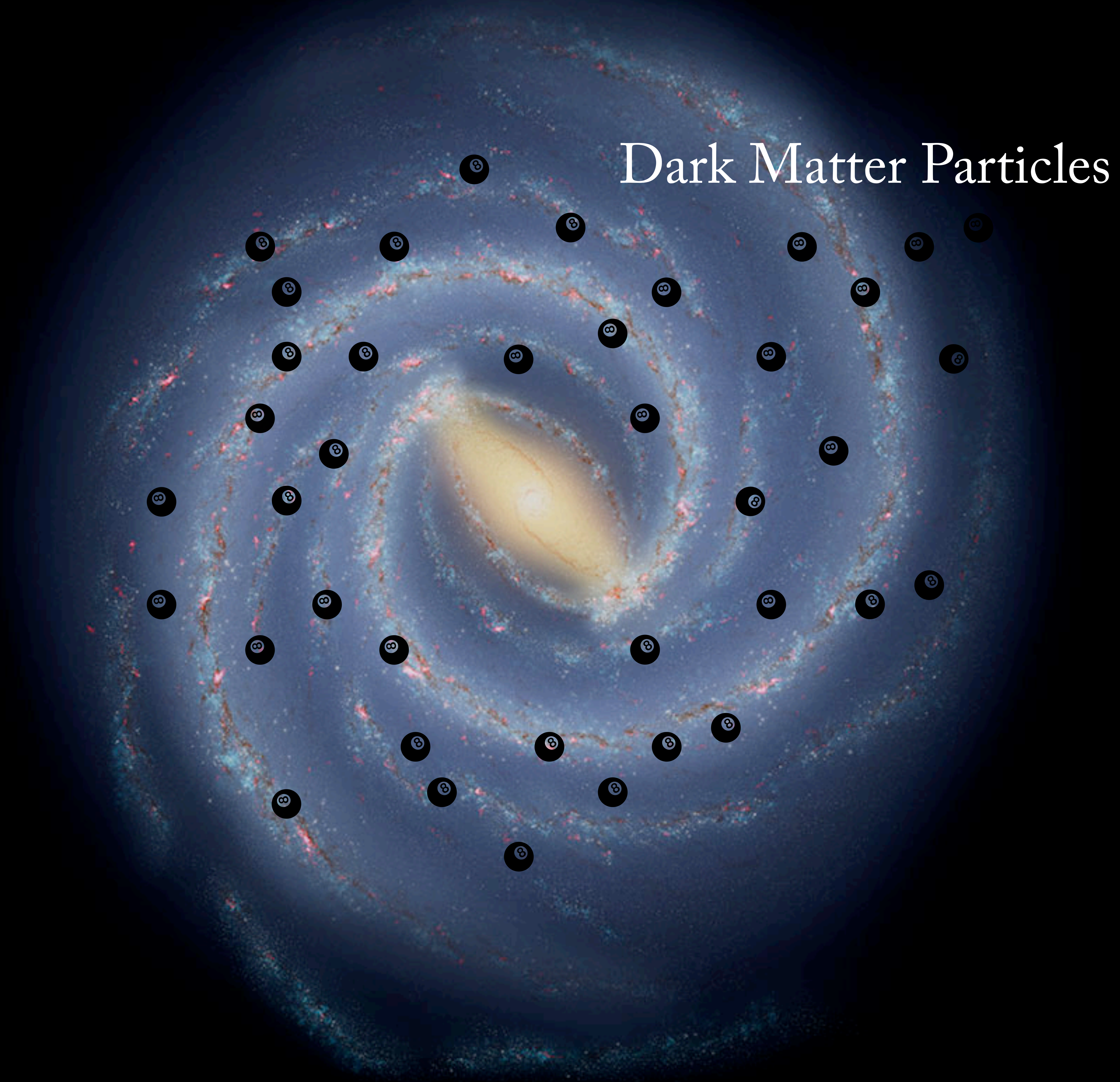
laura.manenti@sydney.edu.au



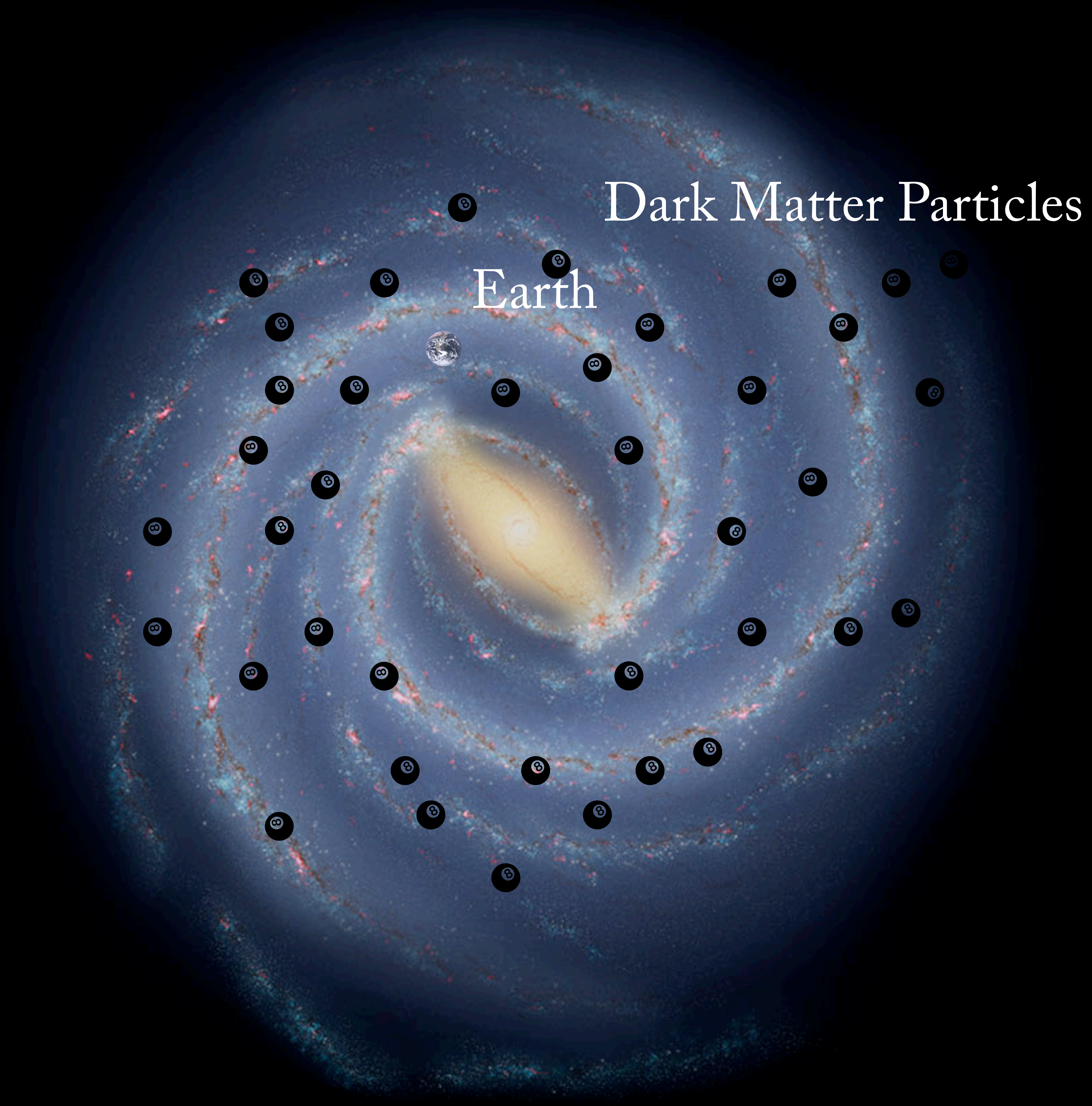
laura.manenti@sydney.edu.au



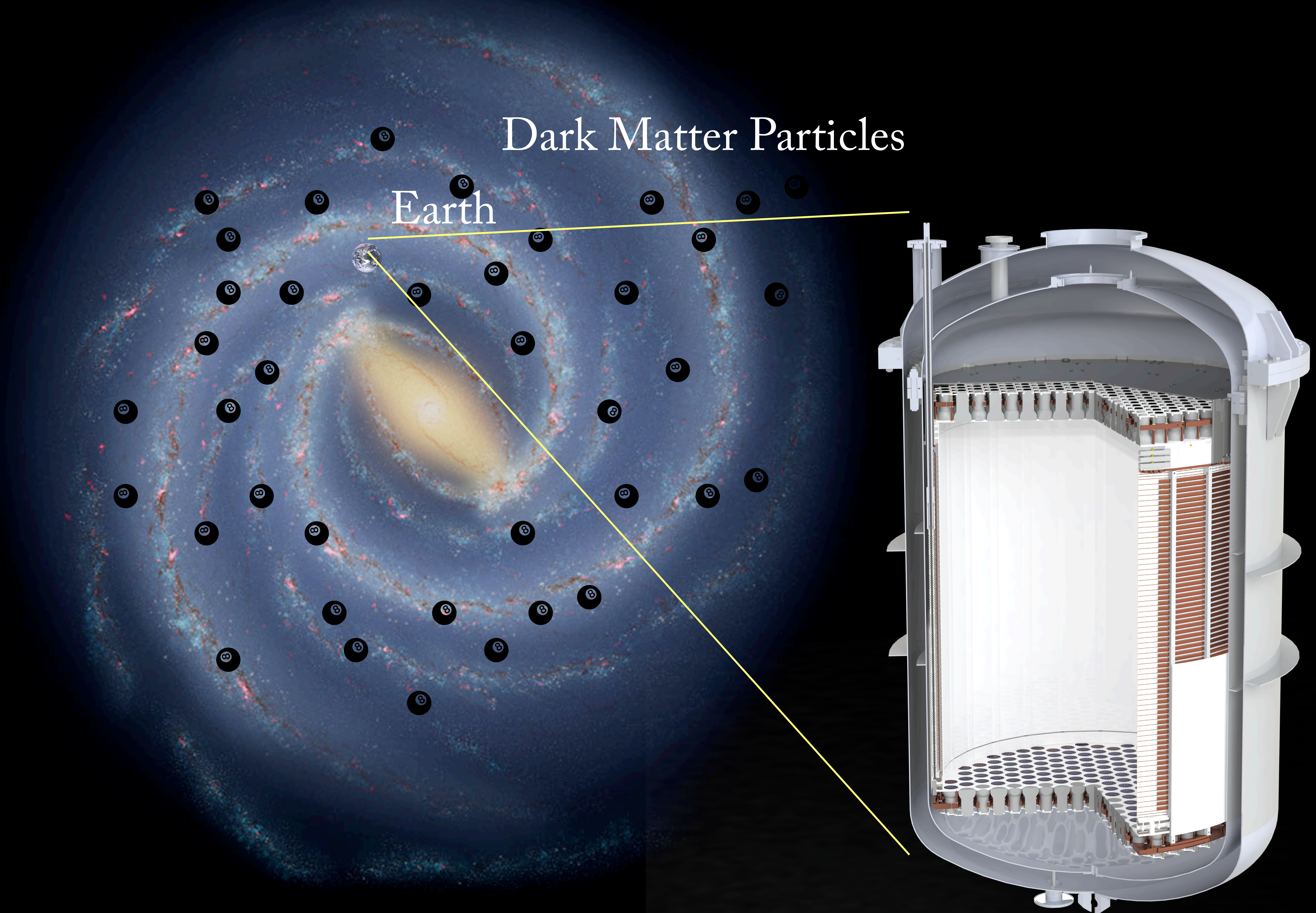
laura.manenti@sydney.edu.au



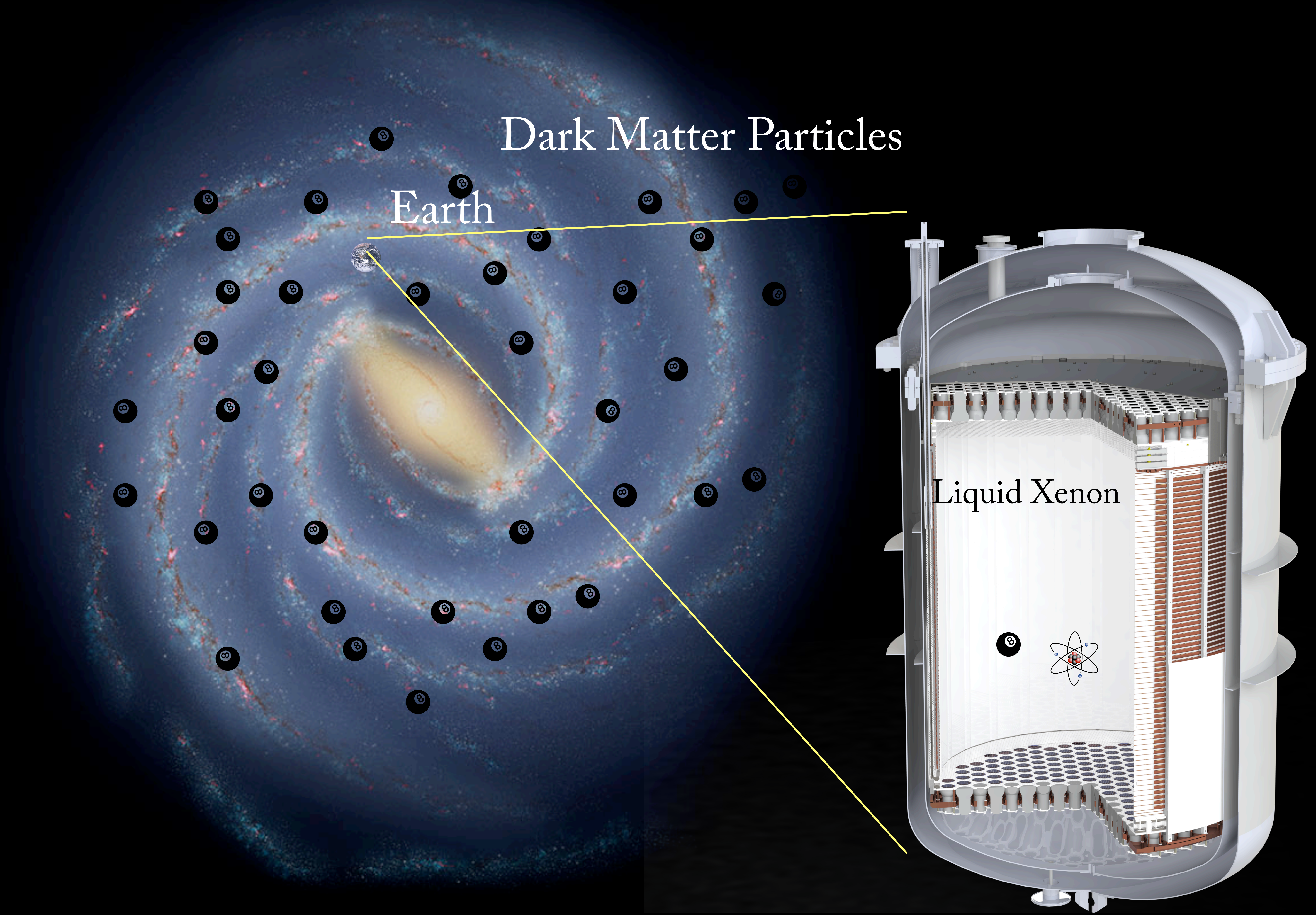
laura.manenti@sydney.edu.au



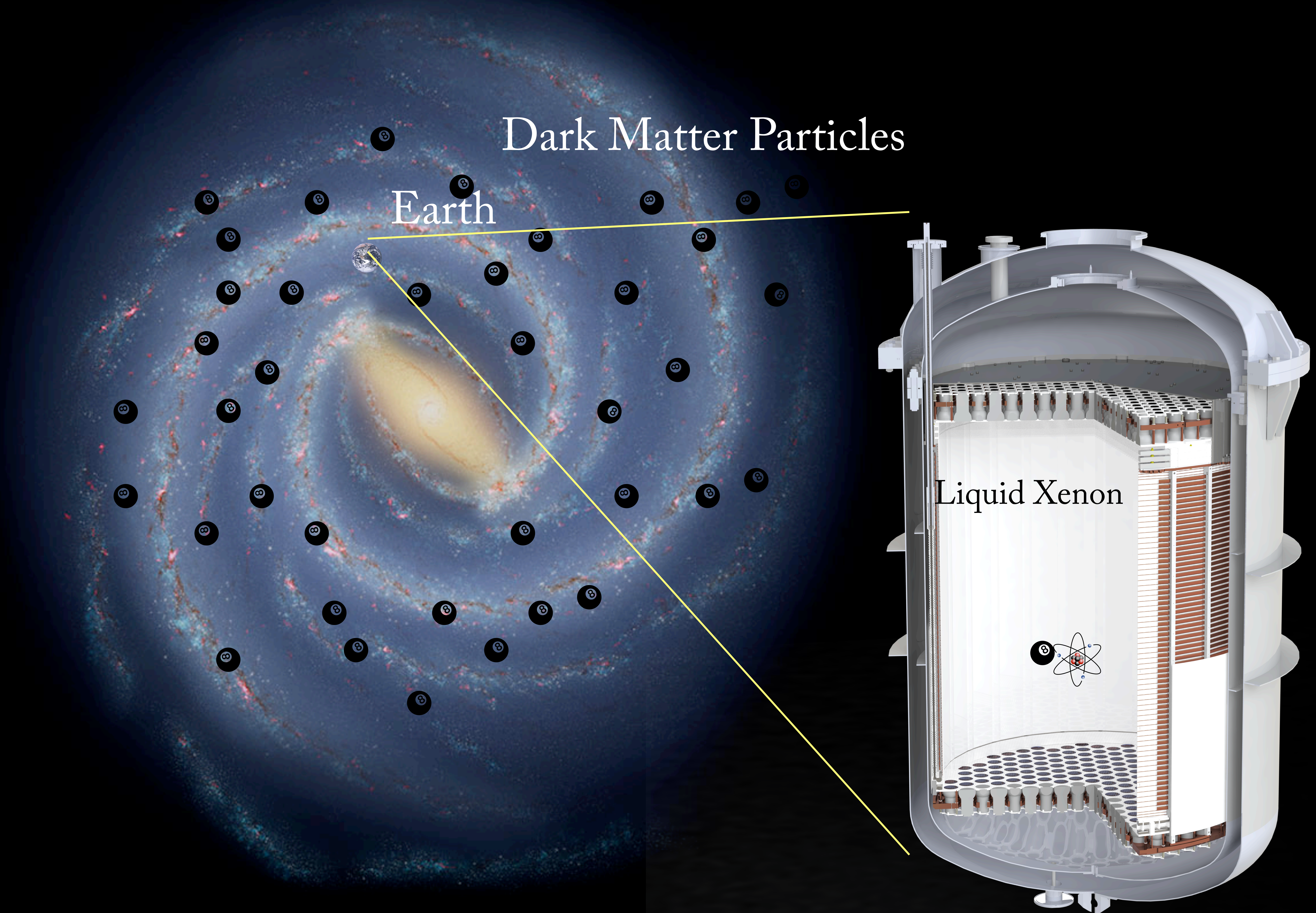
laura.manenti@sydney.edu.au



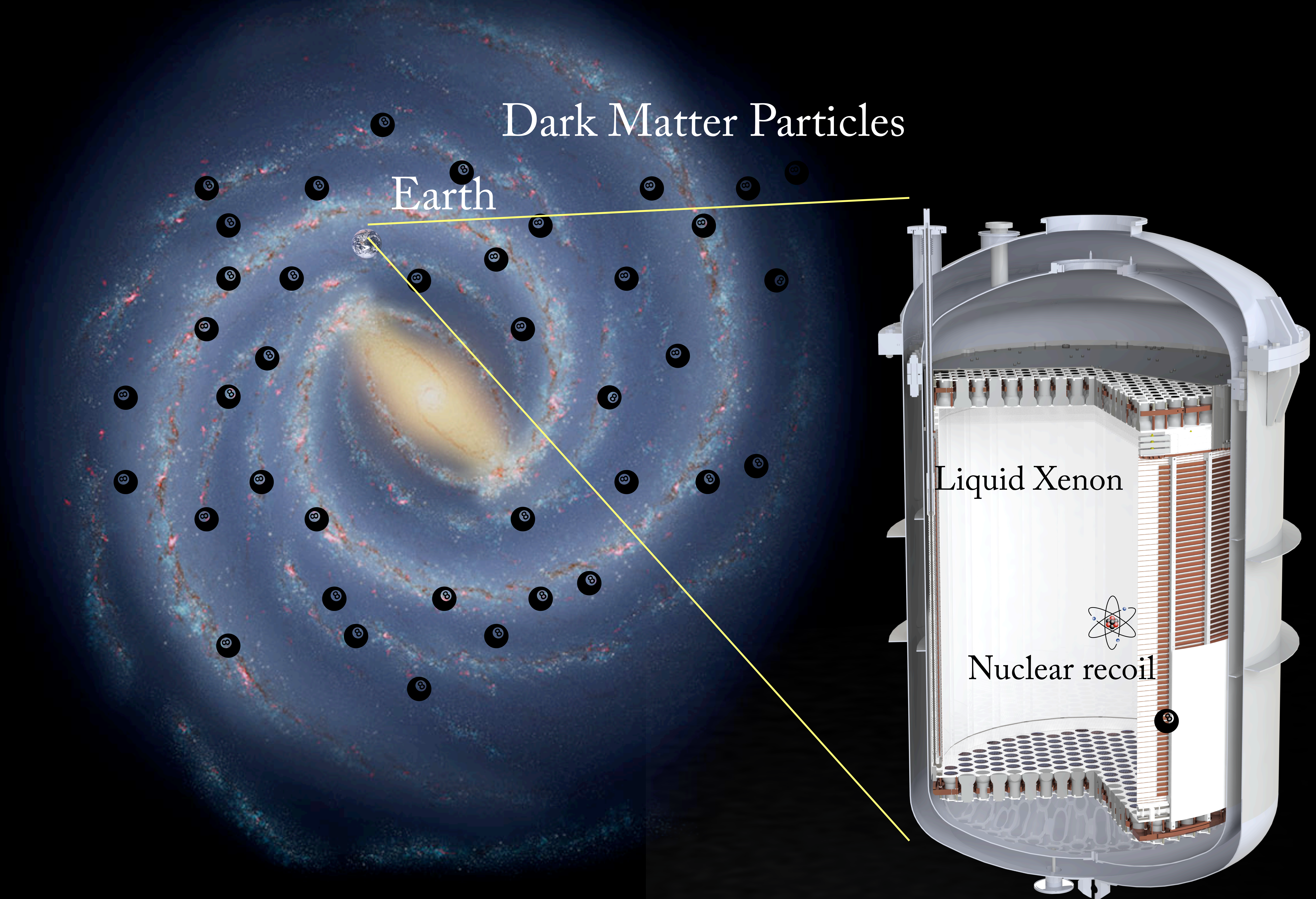
laura.manenti@sydney.edu.au



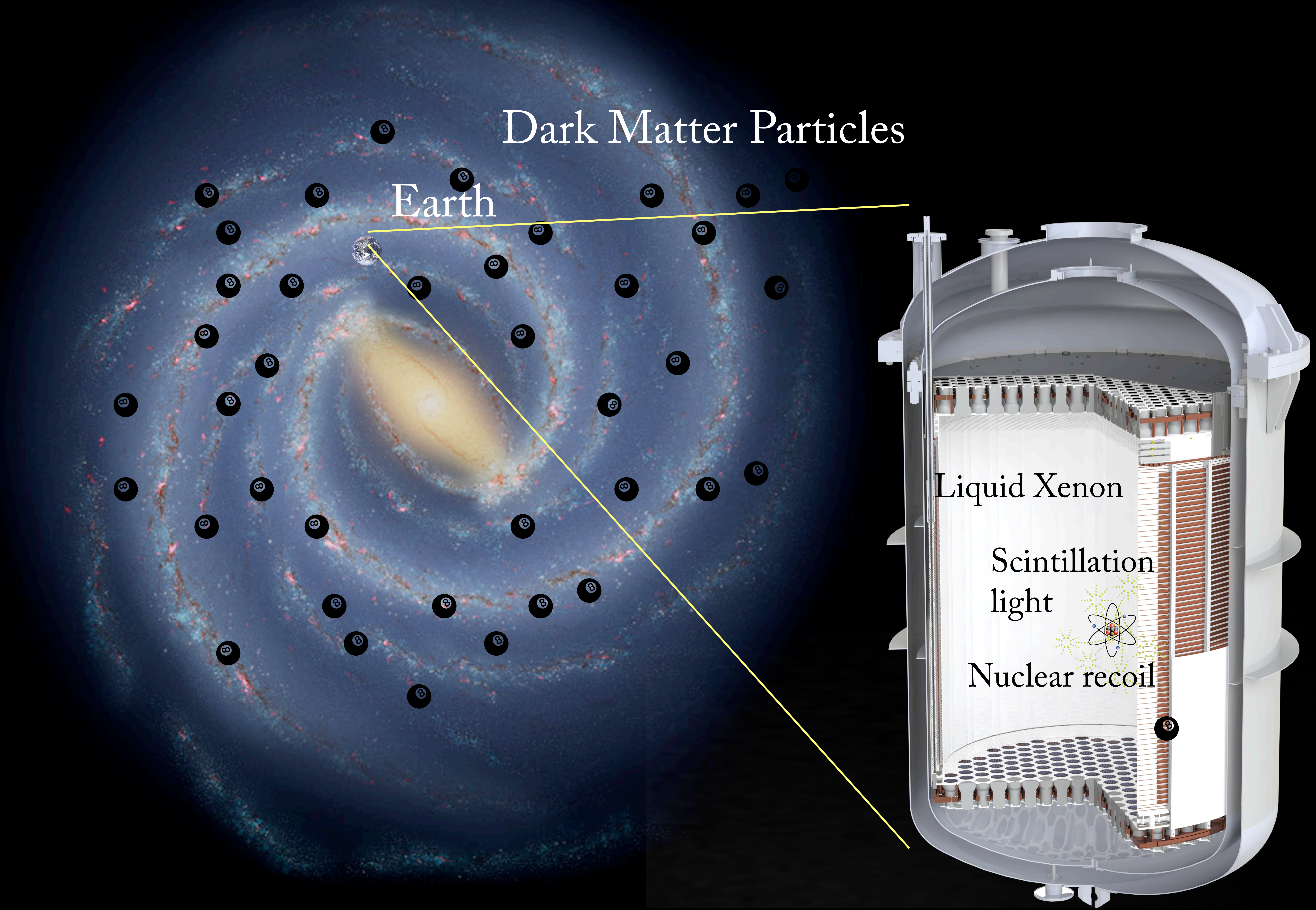
laura.manenti@sydney.edu.au



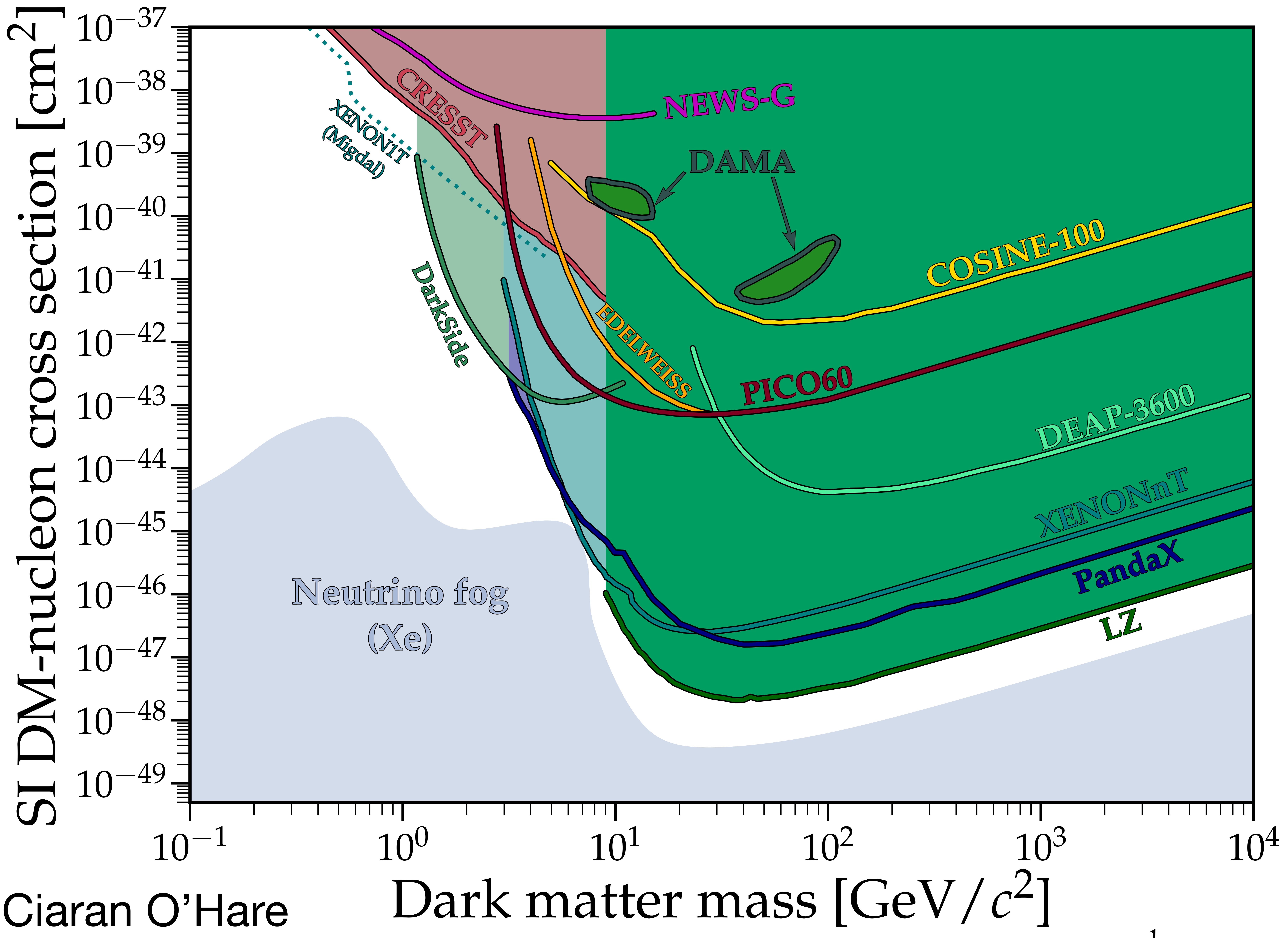
laura.manenti@sydney.edu.au



laura.manenti@sydney.edu.au



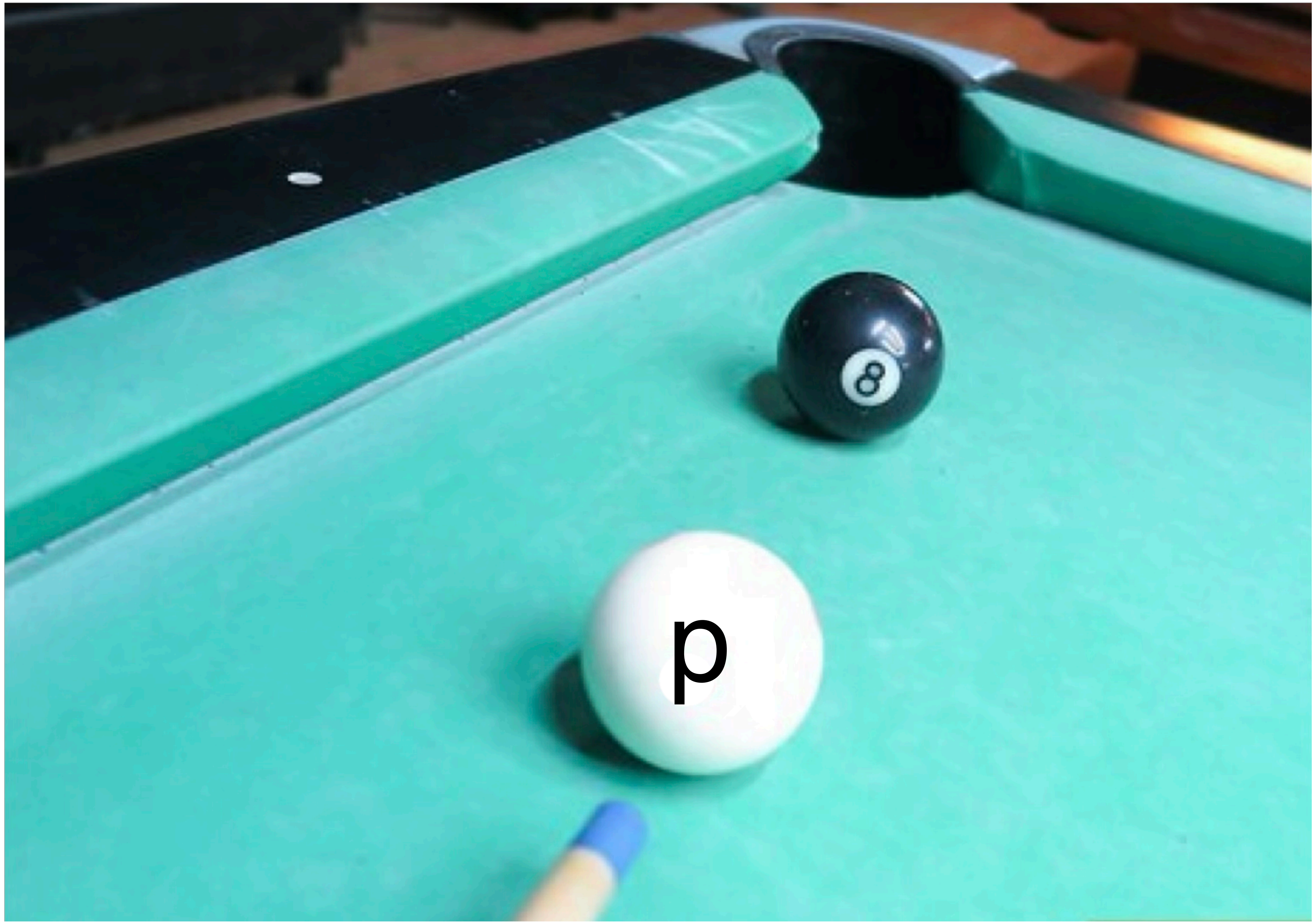
laura.manenti@sydney.edu.au



Credit: Ciaran O'Hare

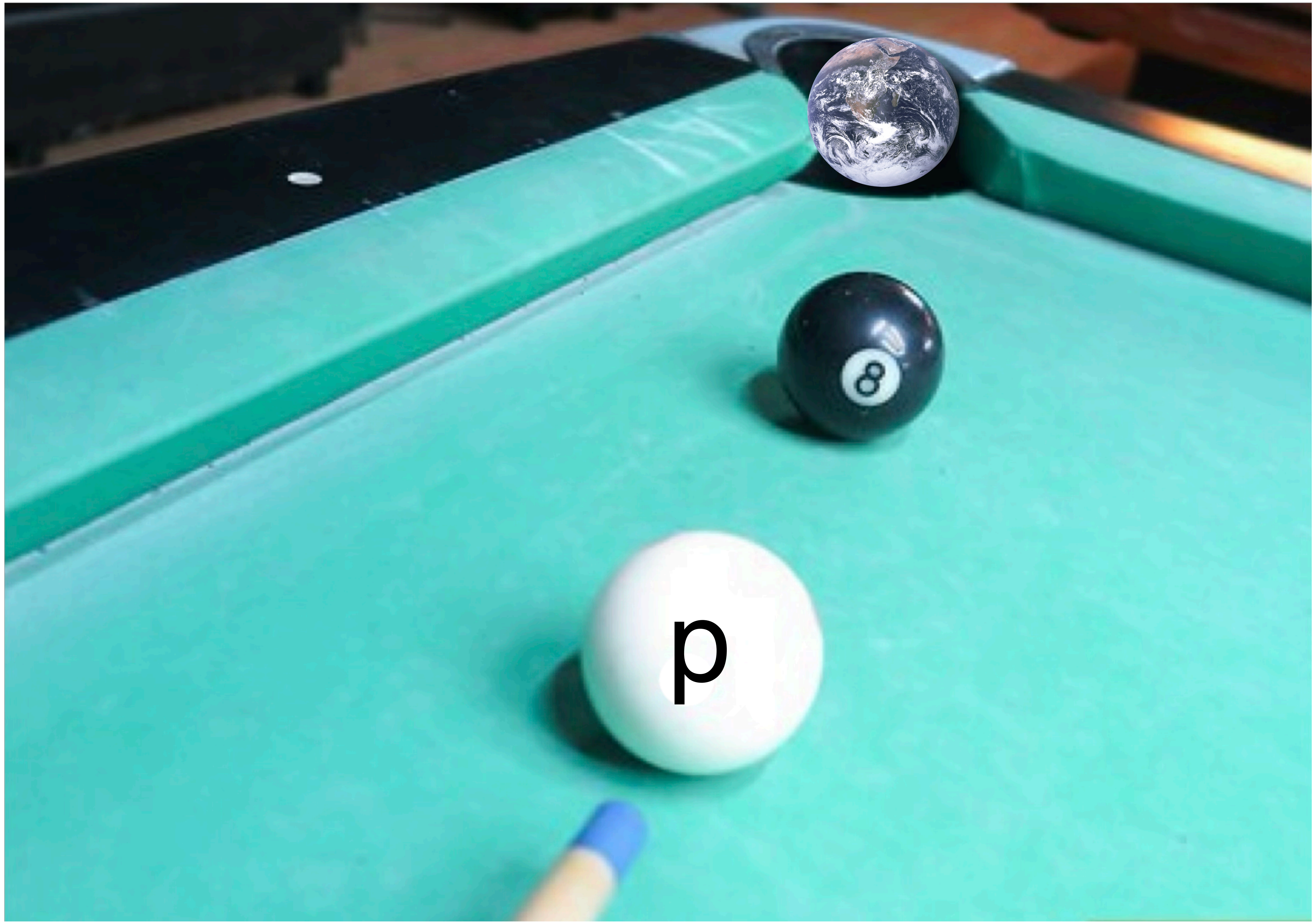
laura.manenti@sydney.edu.au

Boosting Dark Matter



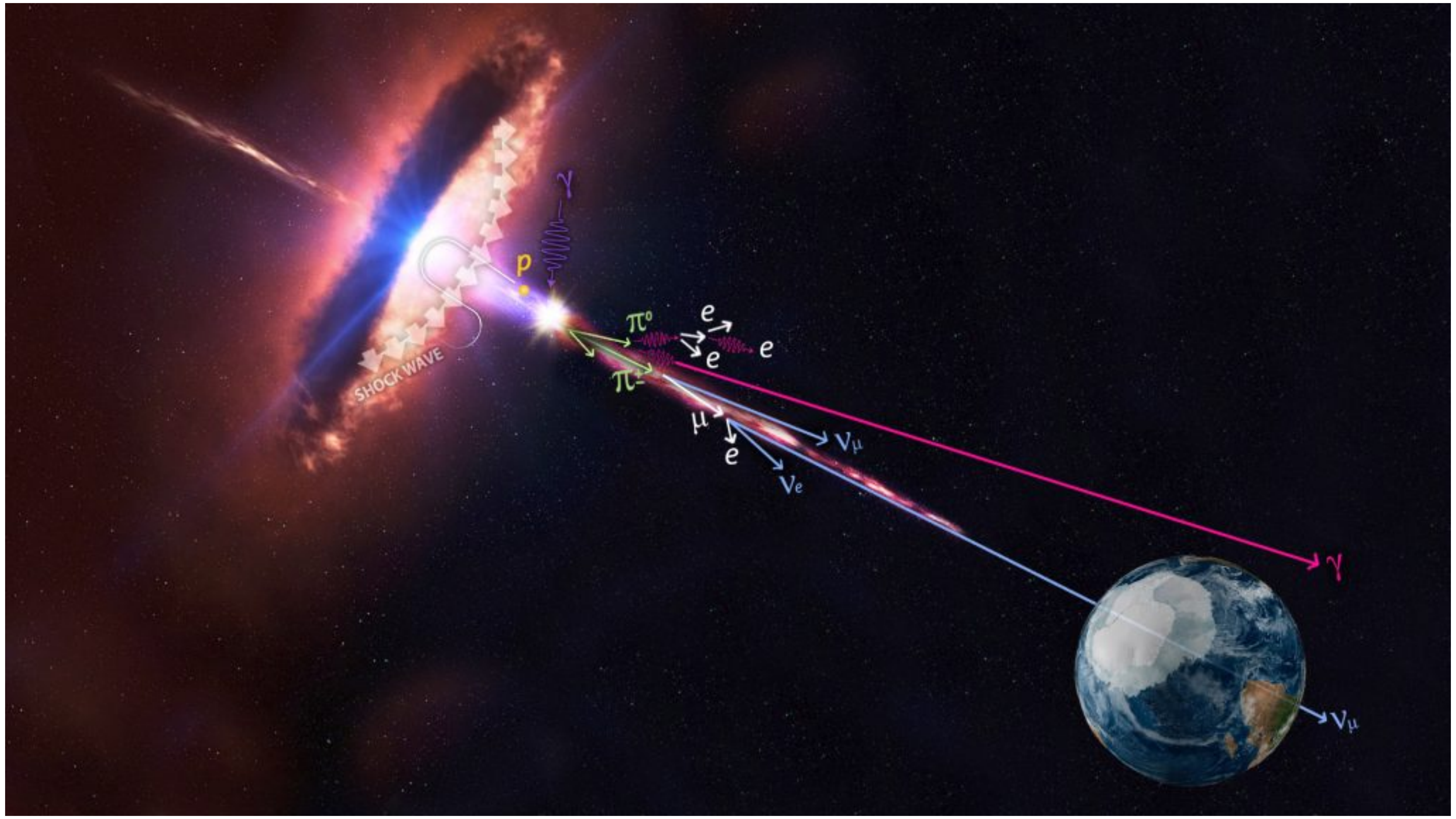
laura.manenti@sydney.edu.au

Boosting Dark Matter



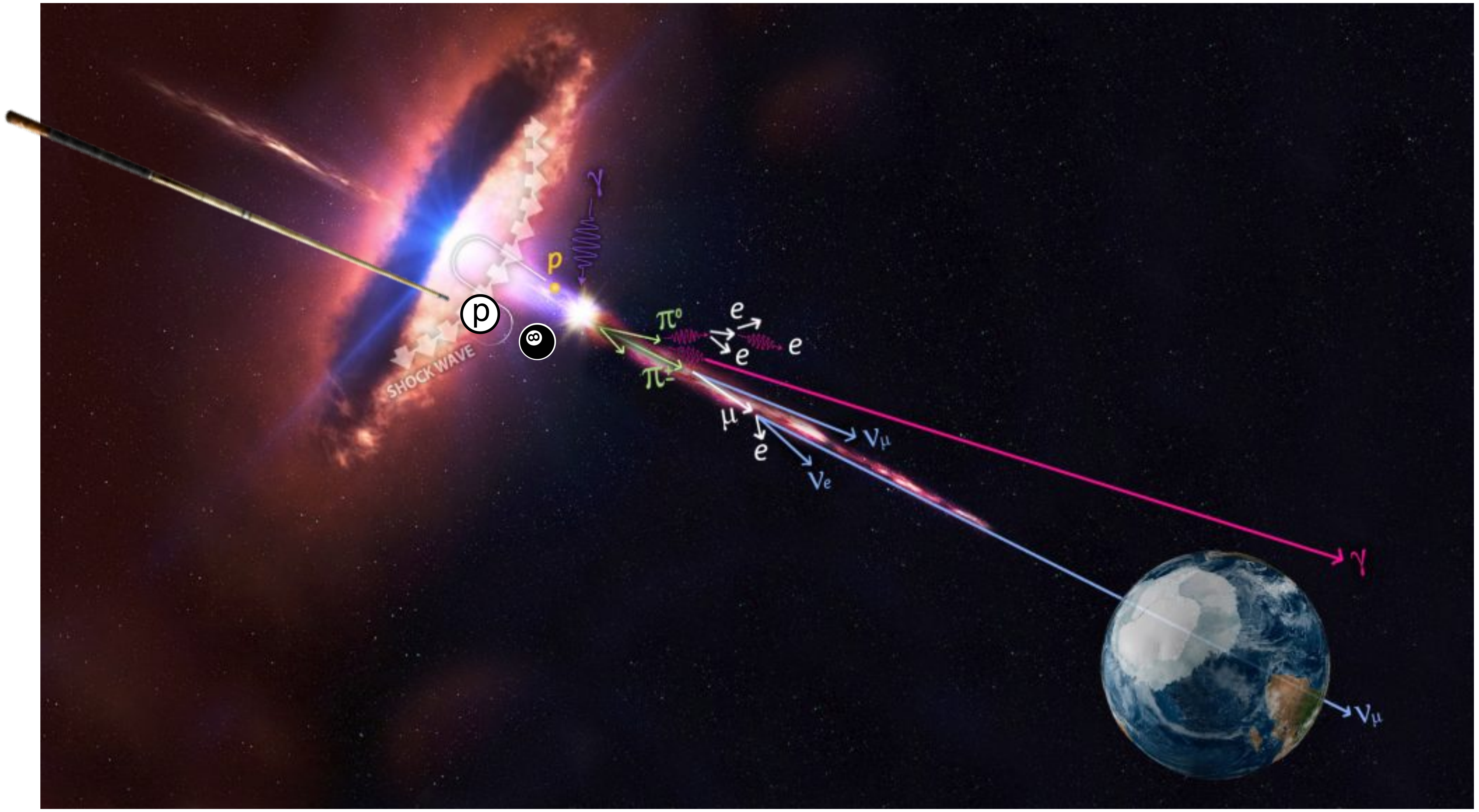
laura.manenti@sydney.edu.au

Boosting Dark Matter



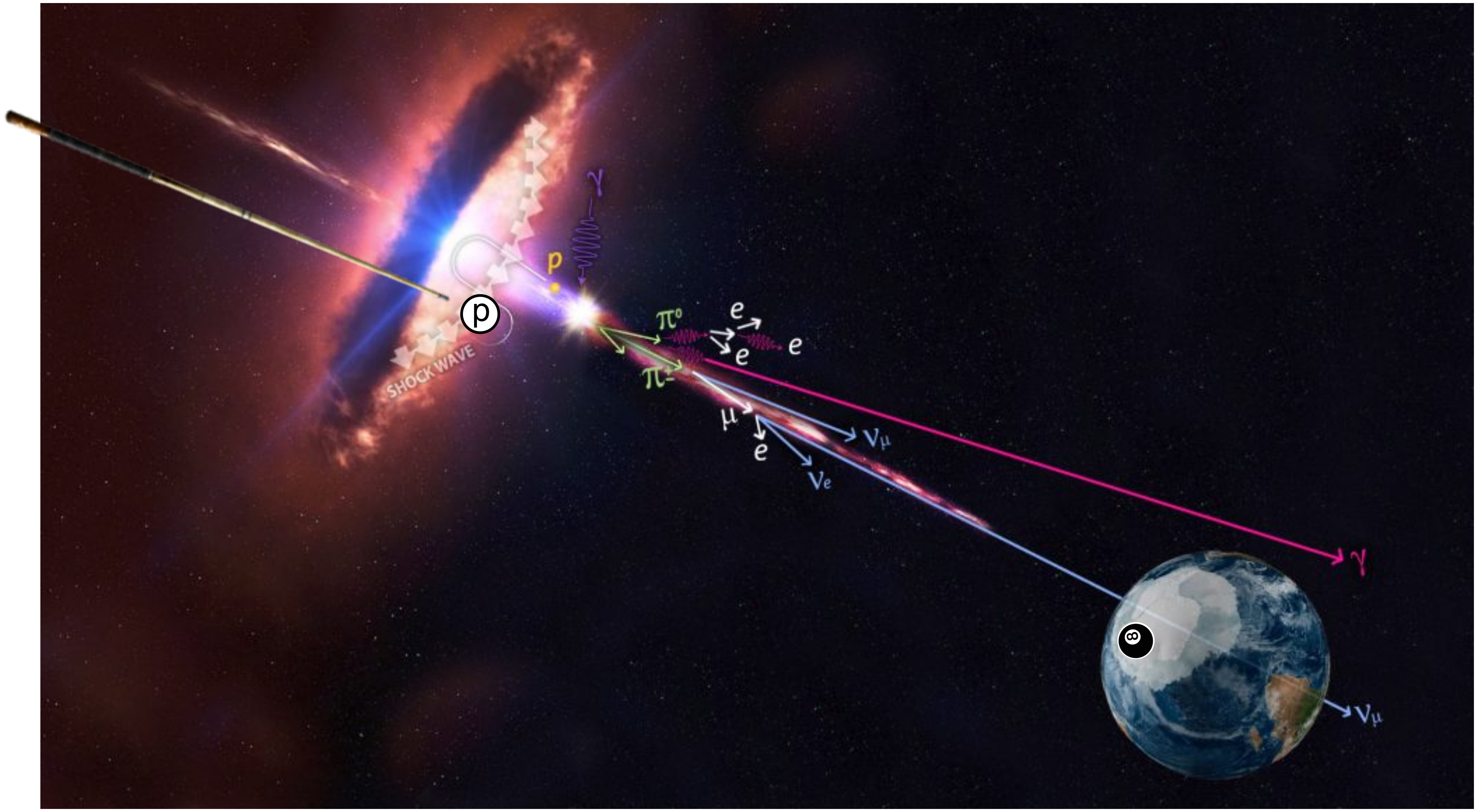
laura.manenti@sydney.edu.au

Boosting Dark Matter



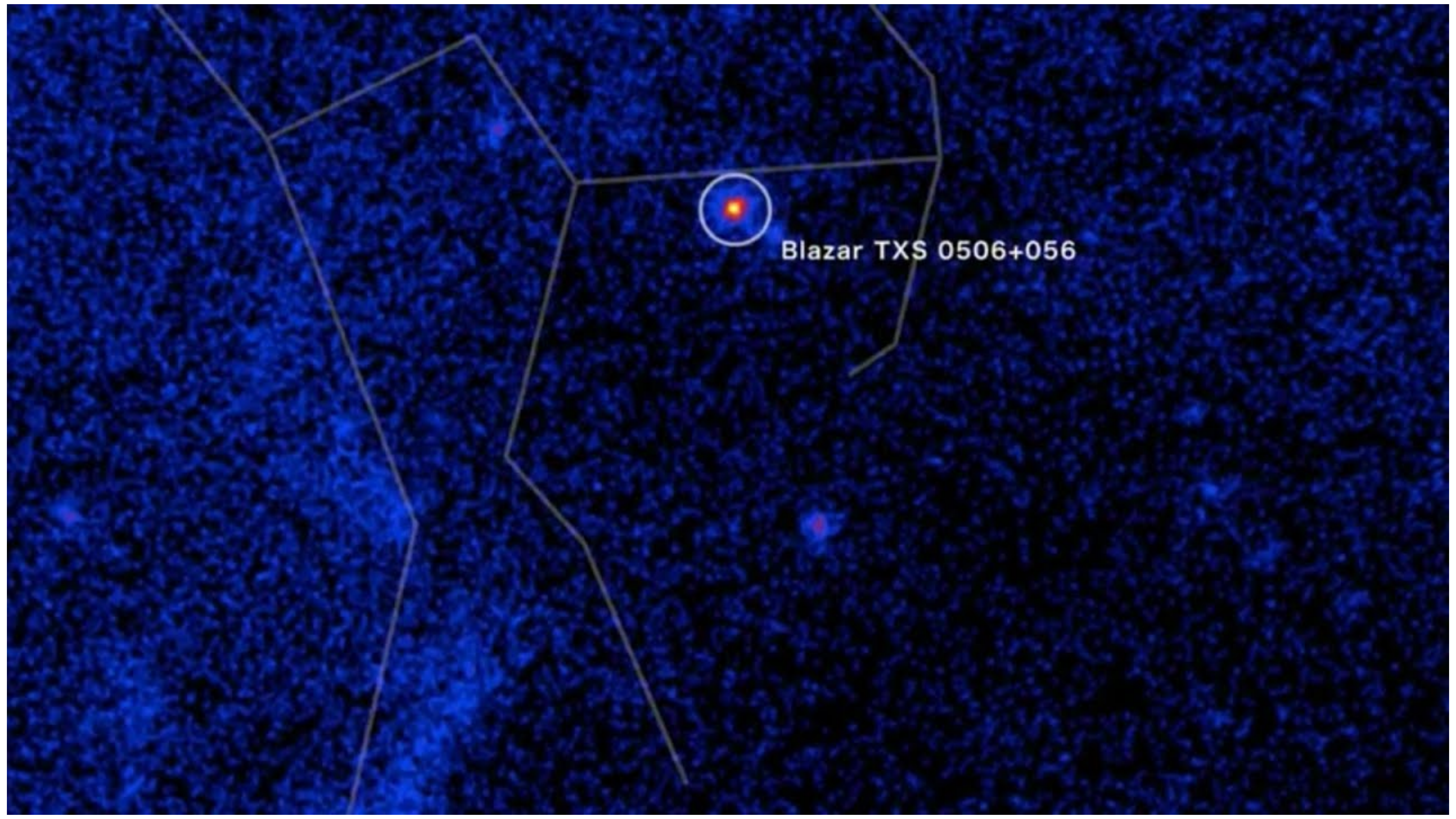
laura.manenti@sydney.edu.au

Boosting Dark Matter



laura.manenti@sydney.edu.au

Source selection



- **Target source:** TXS 0506+056 — 3.75Gyr away
- **Jet composition:** Only blazar linked to IceCube neutrinos → evidence for hadronic processes
- **Interaction assumed:** Proton–WIMP → same interaction at source and detector
- **Motivation:** Matches Xenon-based nuclear recoil assumption (WIMP–nucleon)
- **Dominant process:** Hadronic > leptonic luminosity in jets
- **Modeling advantage:** TXS 0506+056 is bright and well-constrained observationally

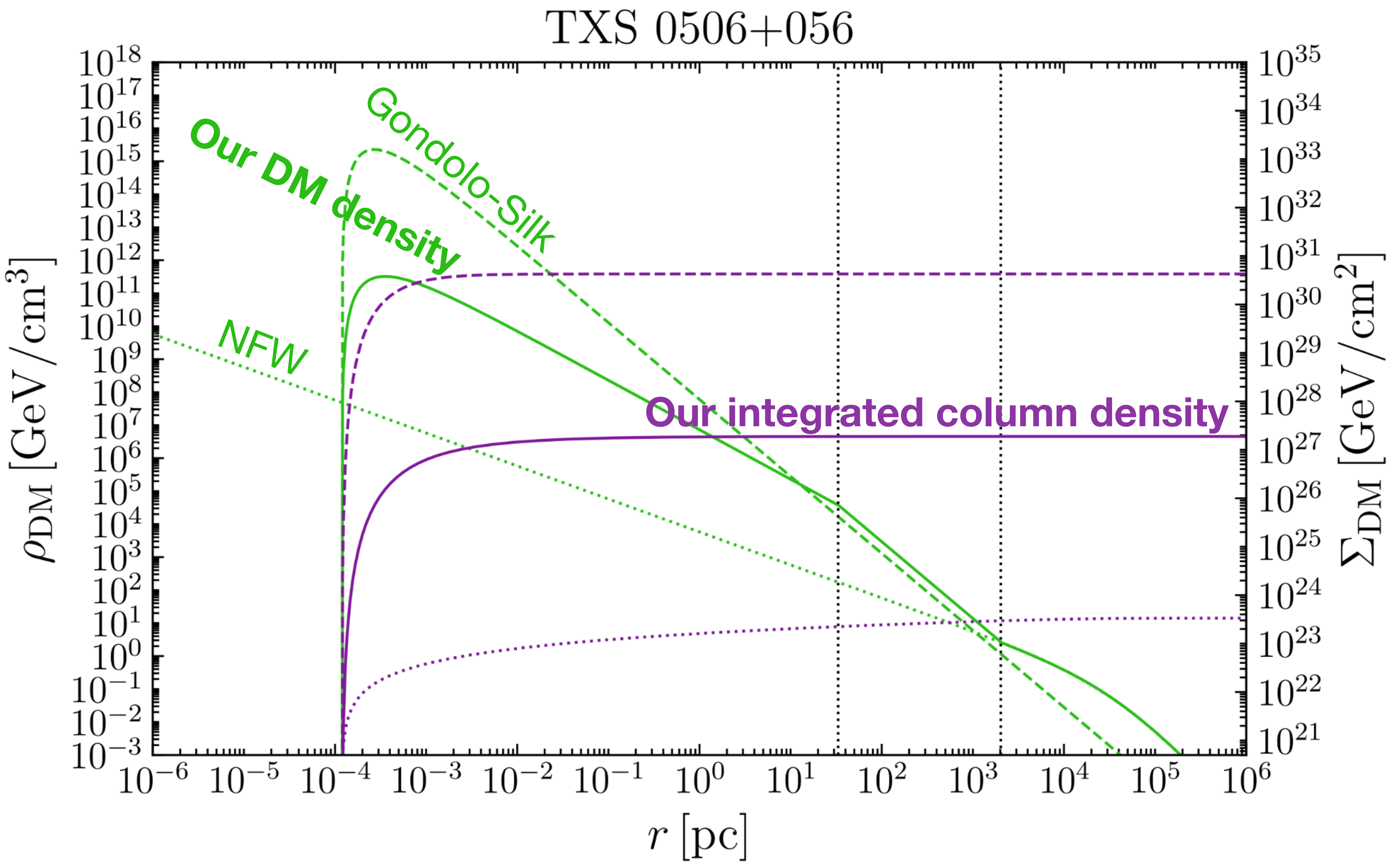
laura.manenti@sydney.edu.au

Dark Matter Profile

3-zone model

We consider a 3-zone model:

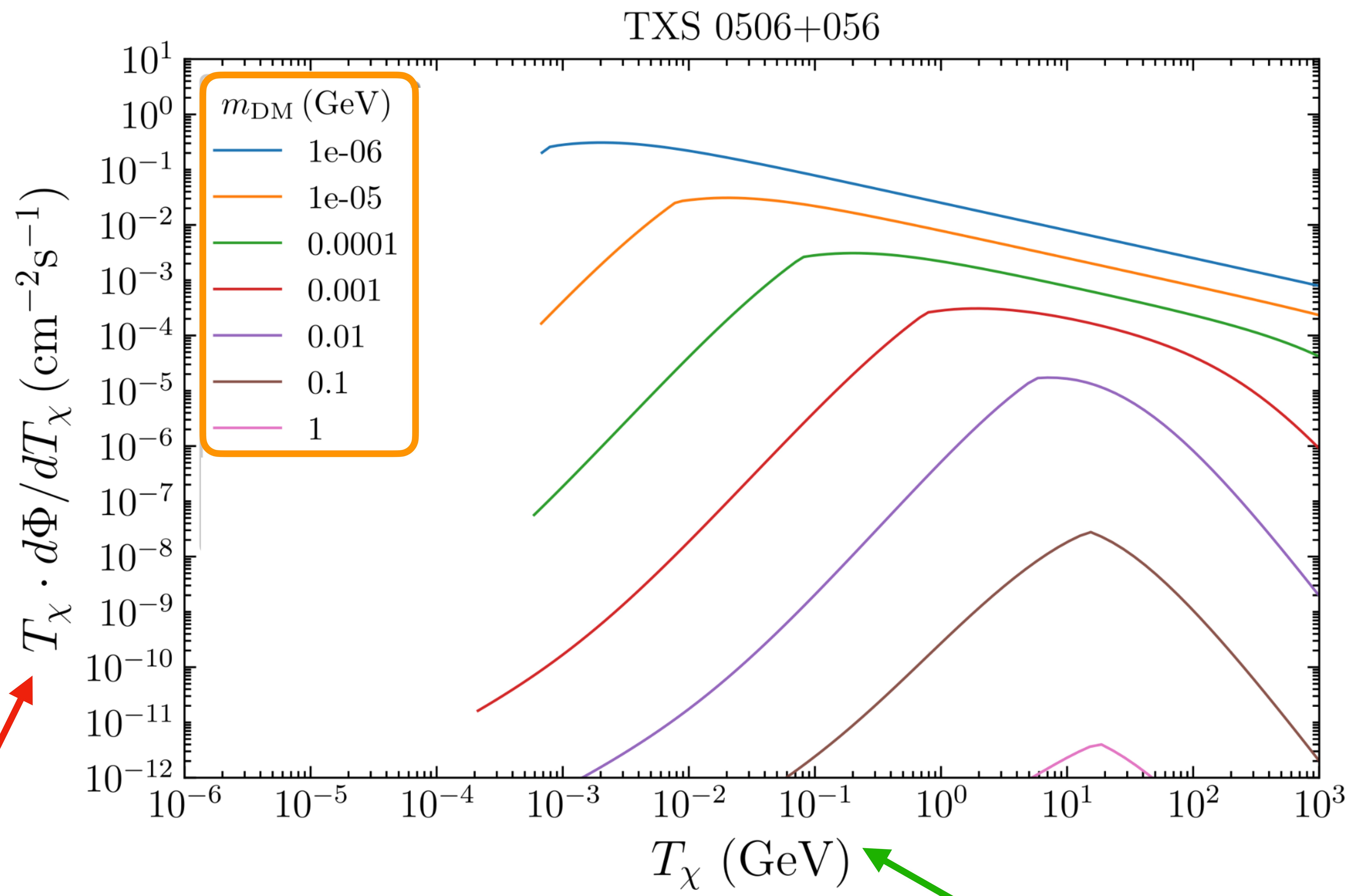
- NFW at high radii
- Gondolo-Silk Spike at intermediate radii
- A flattening from baryonic effects at low radii (at very small radii, capture by the black hole leads to a loss of dark matter).



$$\rho_{3Z}(r) = \left(1 - \frac{4R_S}{r}\right)^3 \rho_{NFW}(R_{\rm sp}) \times \begin{cases} 0 & r \leq 4R_S \\ (R_{\rm SP}/R_i)^{7/3} (R_i/r)^{3/2} & 4R_S < r \leq R_i \\ (R_{sp}/r)^{7/3} & R_{\rm i} < r \leq R_{sp} \\ \rho_{NFW}(r)/\rho_{NFW}(R_{sp}) & r > R_{sp} \end{cases}$$

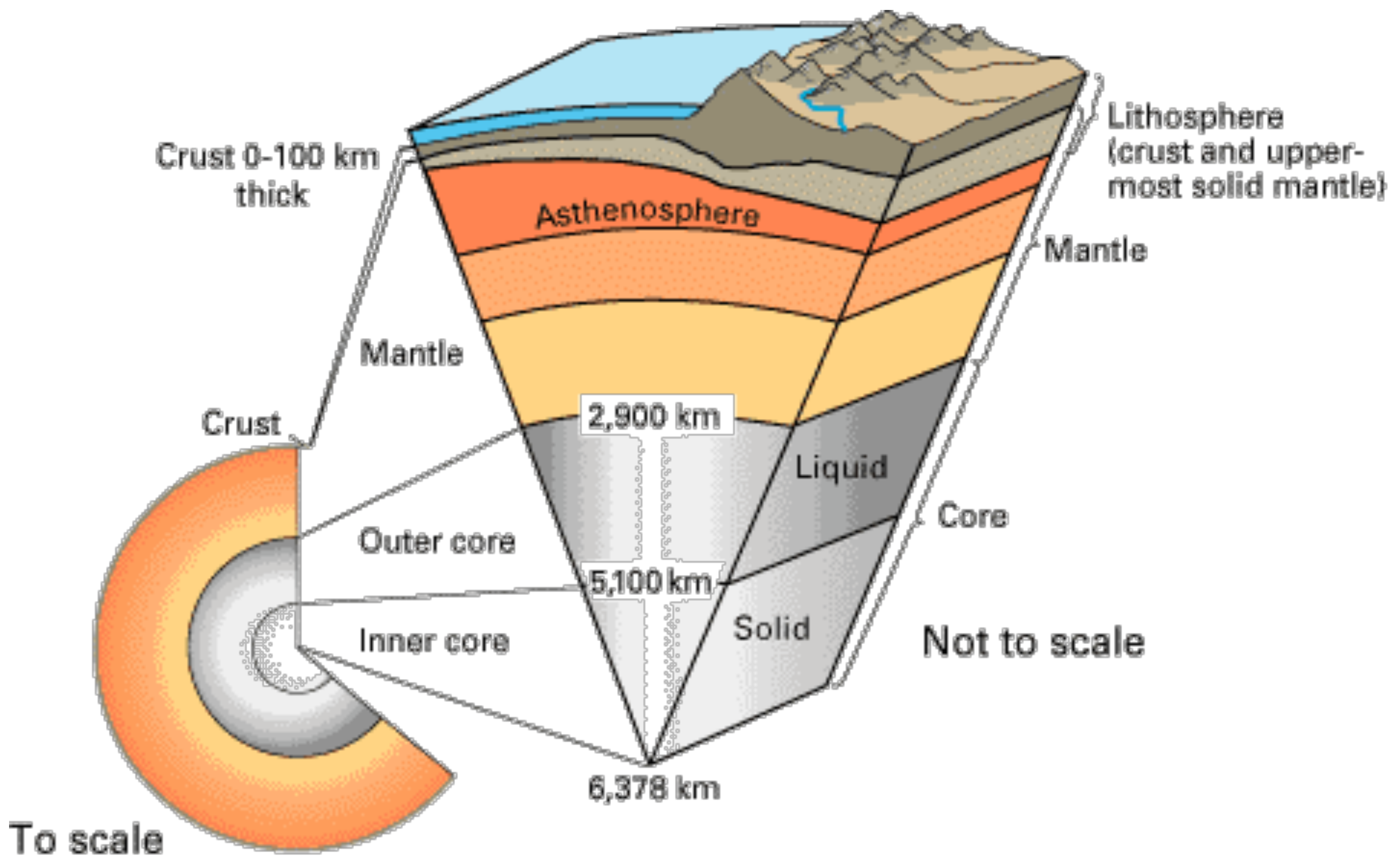
laura.manenti@sydney.edu.au

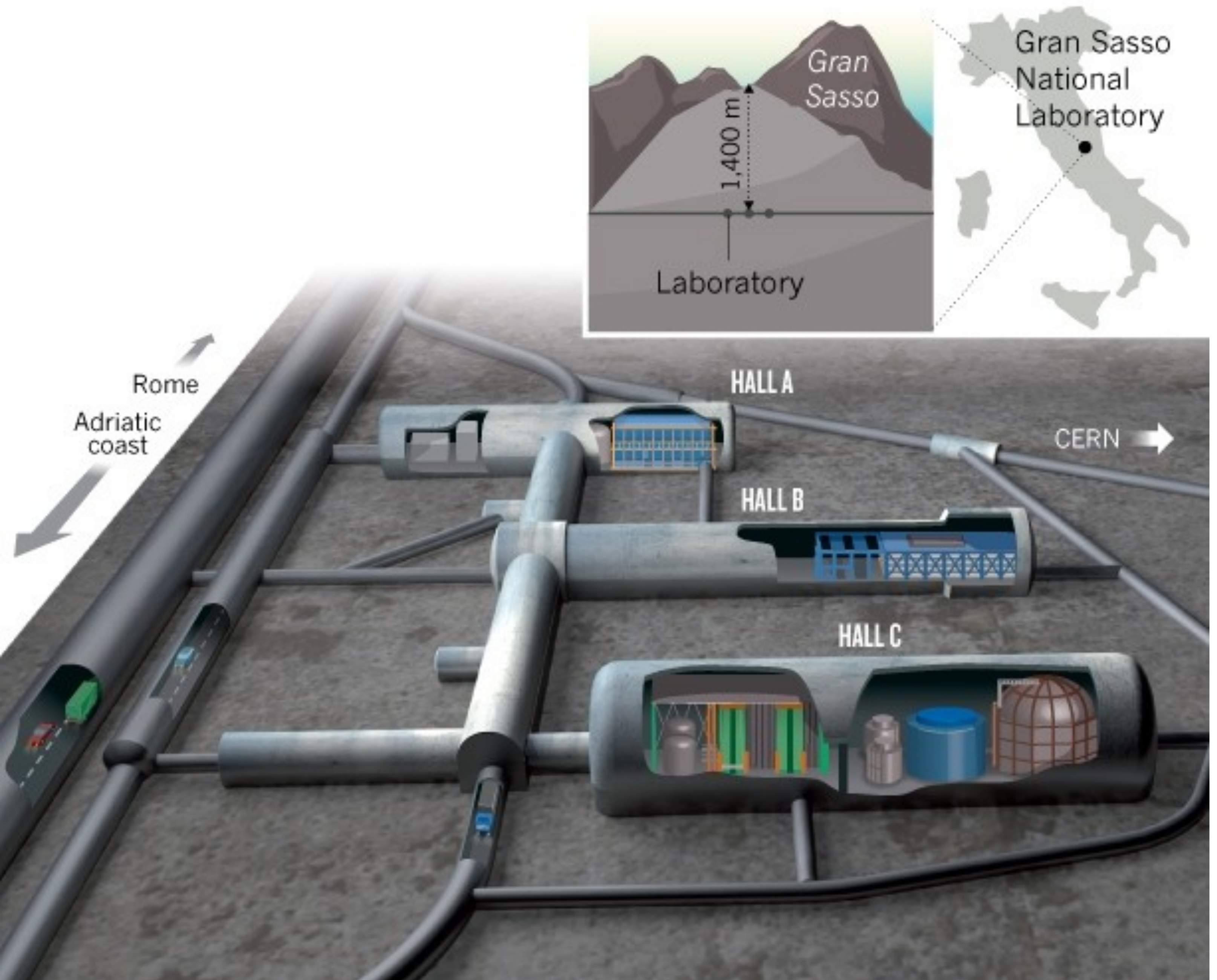
Blazar Boosted Dark Matter on Earth



DM flux on Earth as a function of DM kinetic energy for different DM masses.

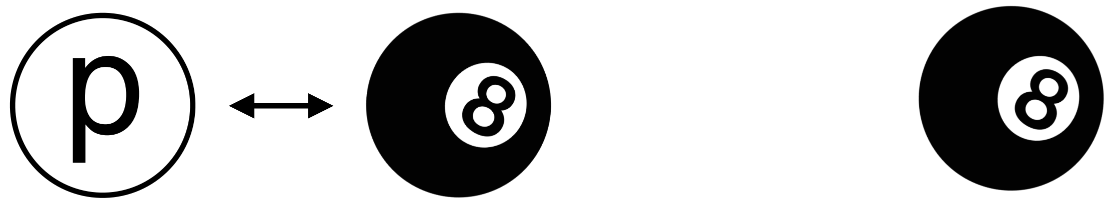
Earth attenuation





Earth attenuation

$\sigma_{\chi p} = 10^{-31}$ cm^2, m_χ=100 MeV



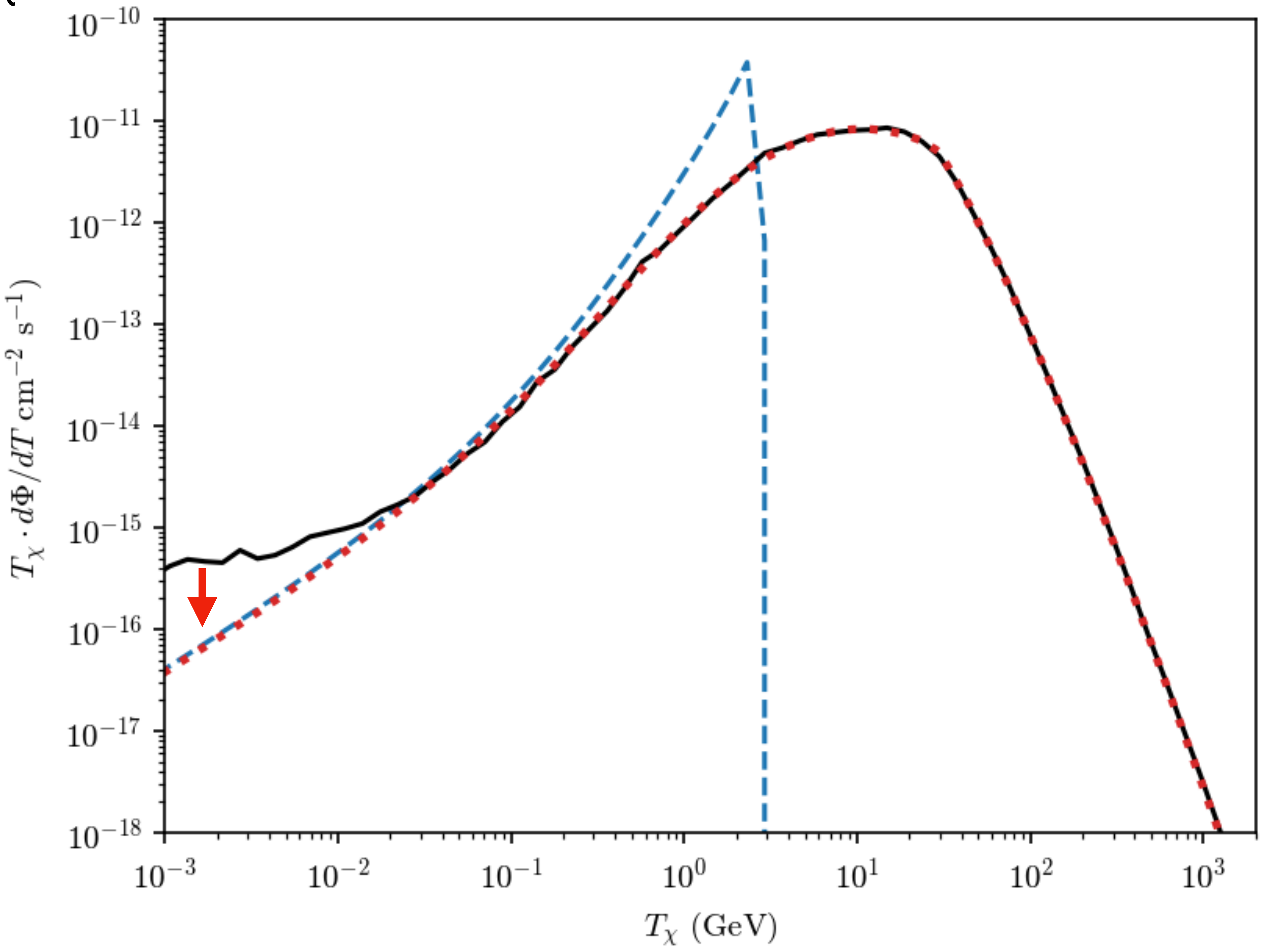
laura.manenti@sydney.edu.au

Earth attenuation

$\sigma_{\chi p} = 10^{-31}$ cm^2, m_χ=100 MeV

Boosted DM flux vs kinetic energy T_χ

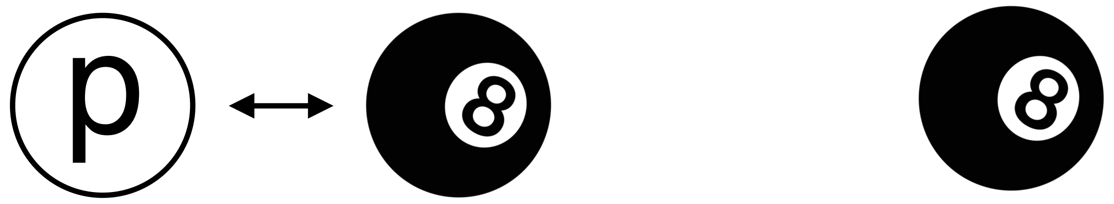
- **Black:** unattenuated flux
- **Blue dashed:** analytical method
- **Red dashed:** numerical method



laura.manenti@sydney.edu.au

Earth attenuation

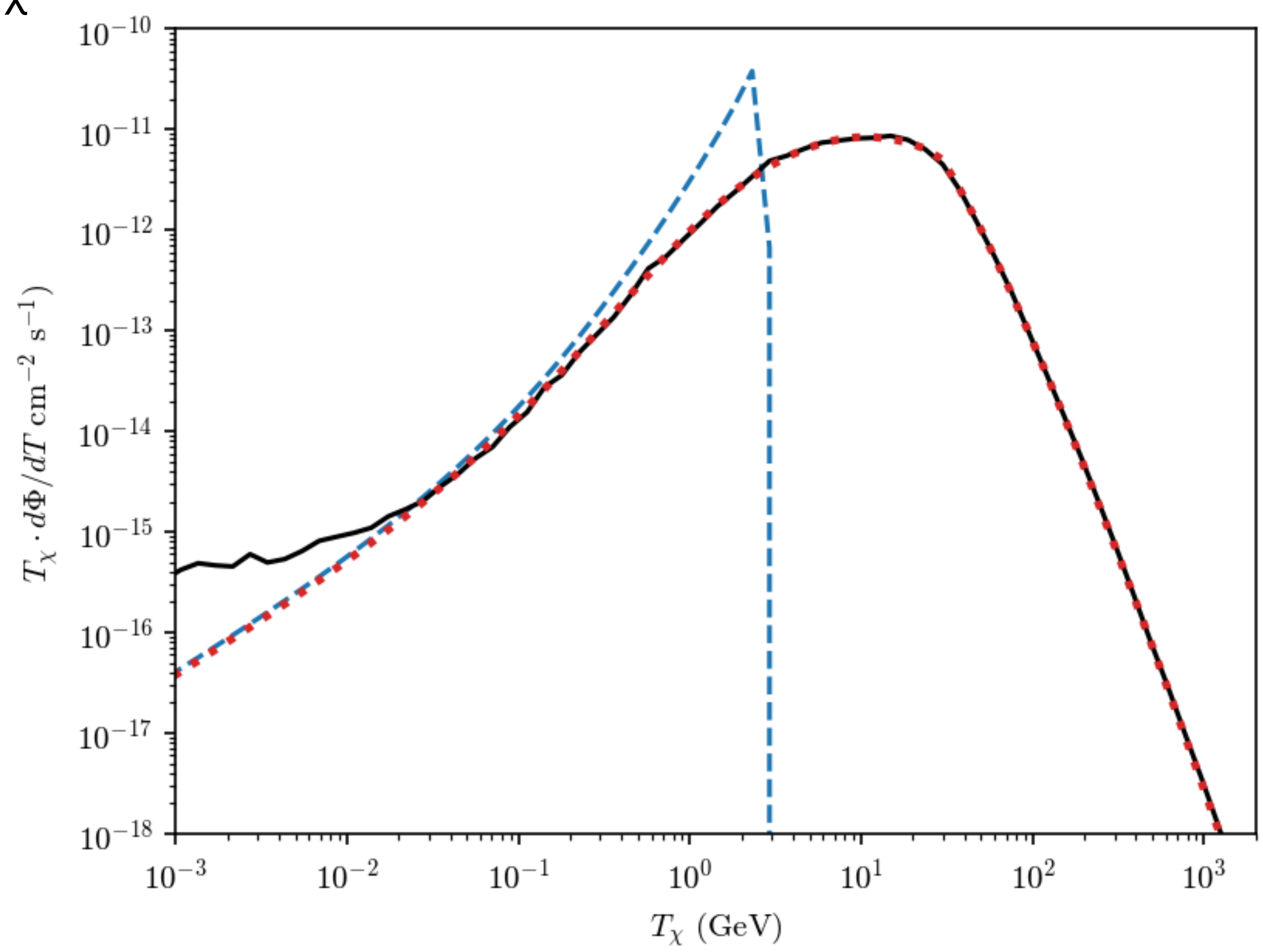
$\sigma_{\chi p} = 10^{-31}$ cm^2, m_χ=100 MeV



Boosted DM flux vs kinetic energy T_χ

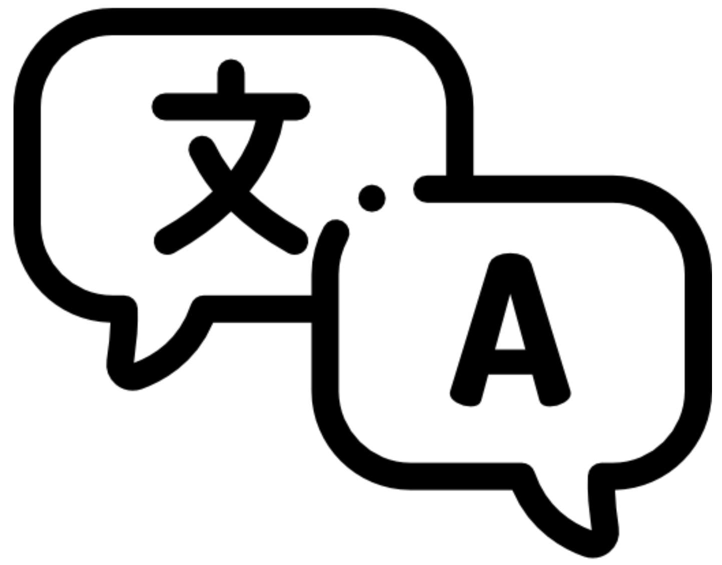
- **Black:** unattenuated flux
- **Blue dashed:** analytical method
- **Red dashed:** numerical method

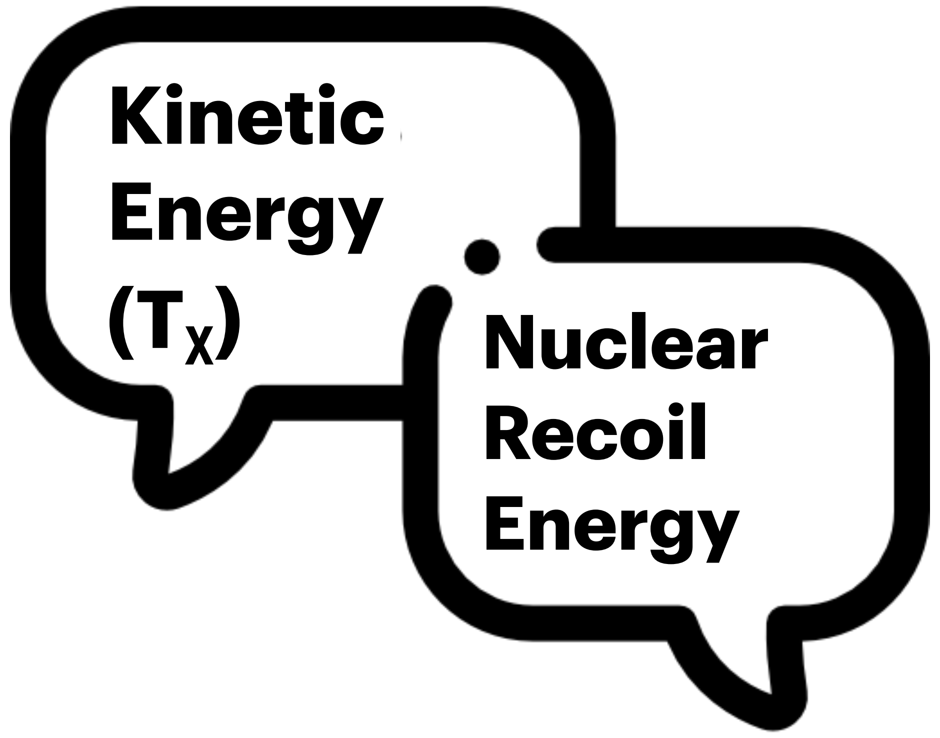
Both approaches predict attenuation effect to vanish near $\sigma_{\chi p} \sim 10^{-31}$cm^2

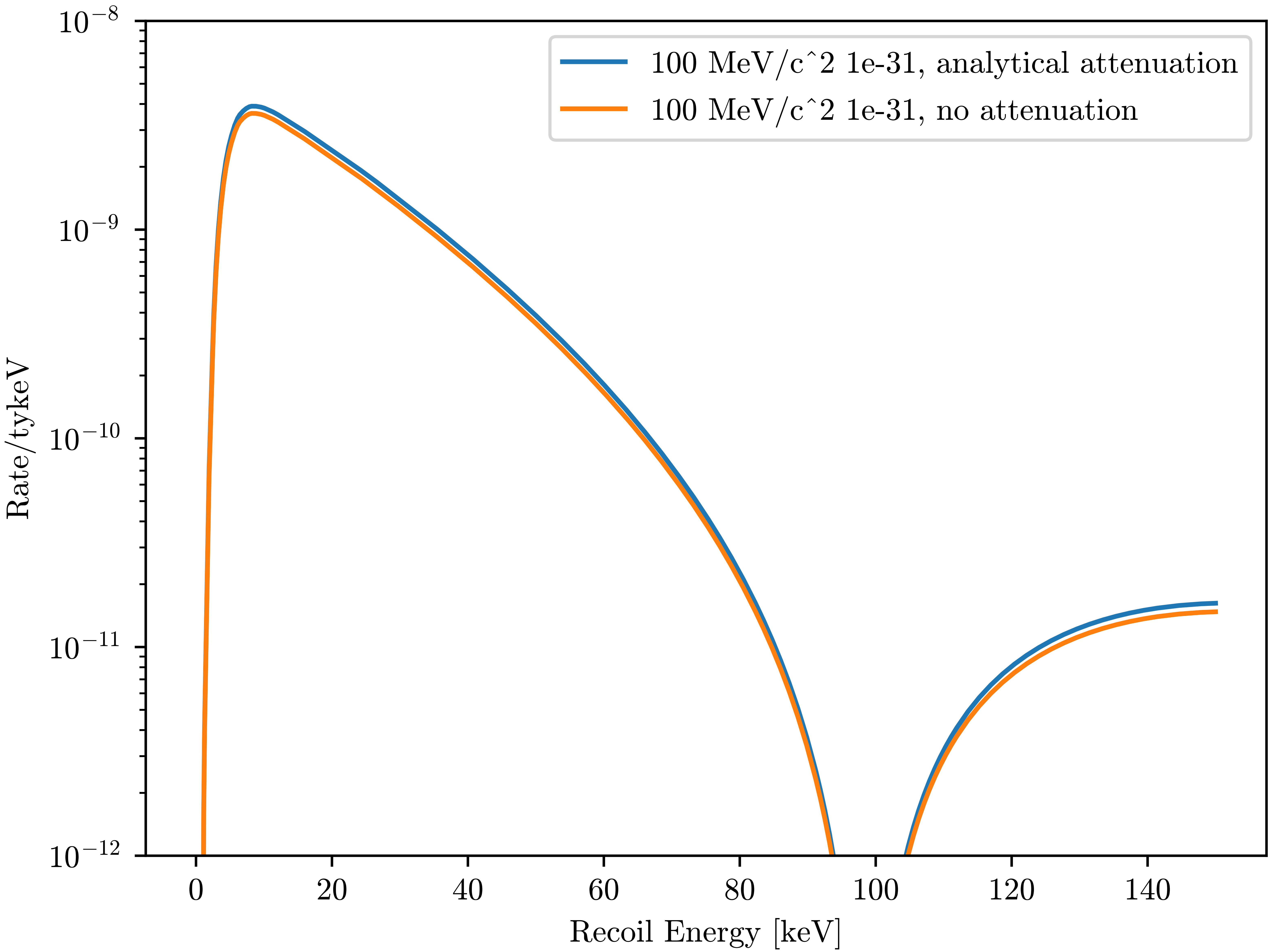


laura.manenti@sydney.edu.au

Predicted rate vs recoil energy at detector







laura.manenti@sydney.edu.au

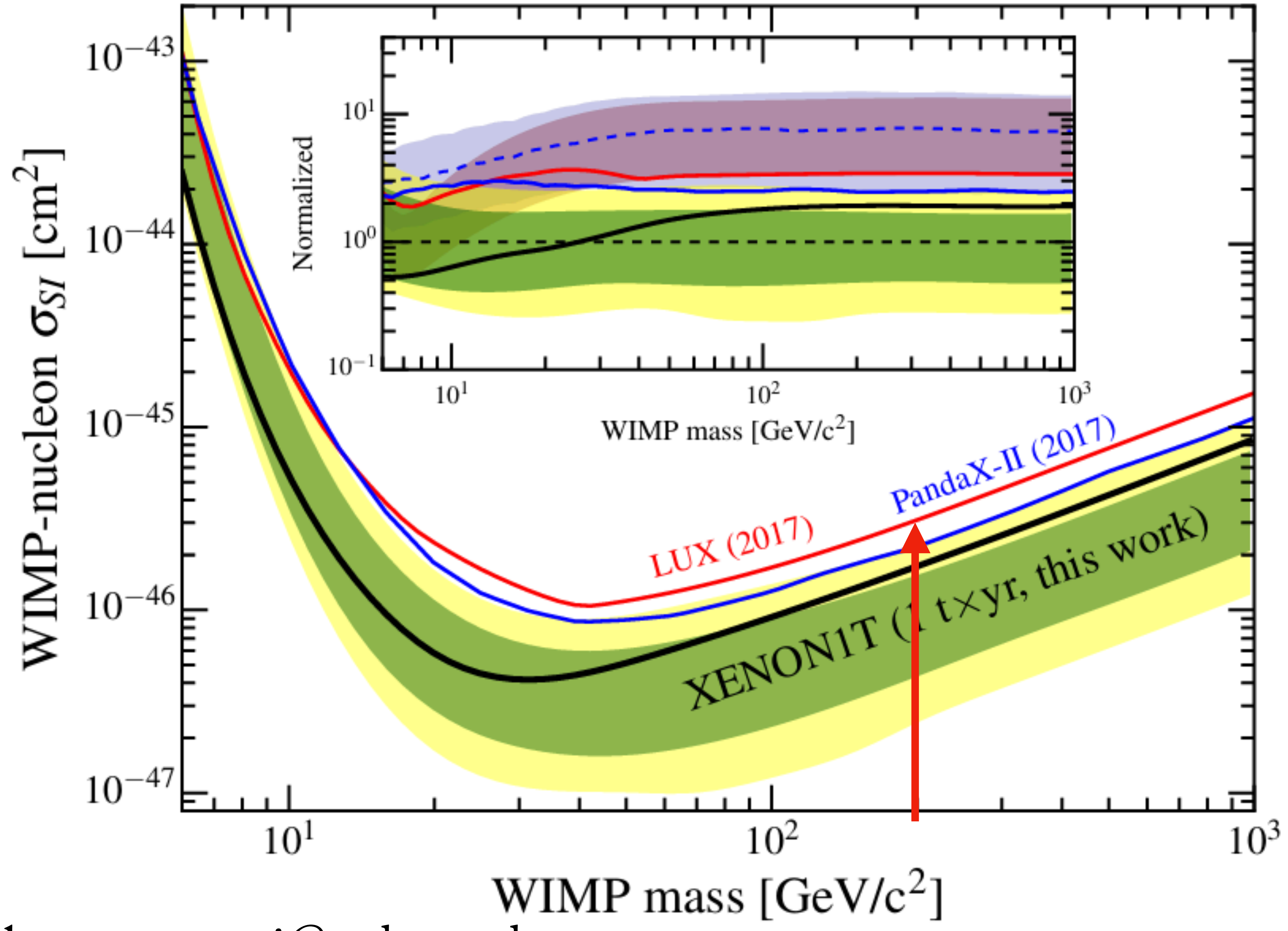
Simple approach to approximate recasting

Rate-matching constraint:

$$R_{\text{excl}} = \sigma^{\text{limit}}_{\text{WIMP}}(200\,\text{GeV}) \times \Phi_{\text{WIMP}} \times \varepsilon_{\text{ROI}}$$

For each BBDM mass, find sigma such that:

$$R_{\text{BBDM}}(m, \sigma) = R_{\text{excl}}$$



Takes experimental limit at one WIMP mass (200 GeV) → "excludes Rate"
Applies same Rate to all BBDM masses: "what cross-section gives that same excluded rate?"

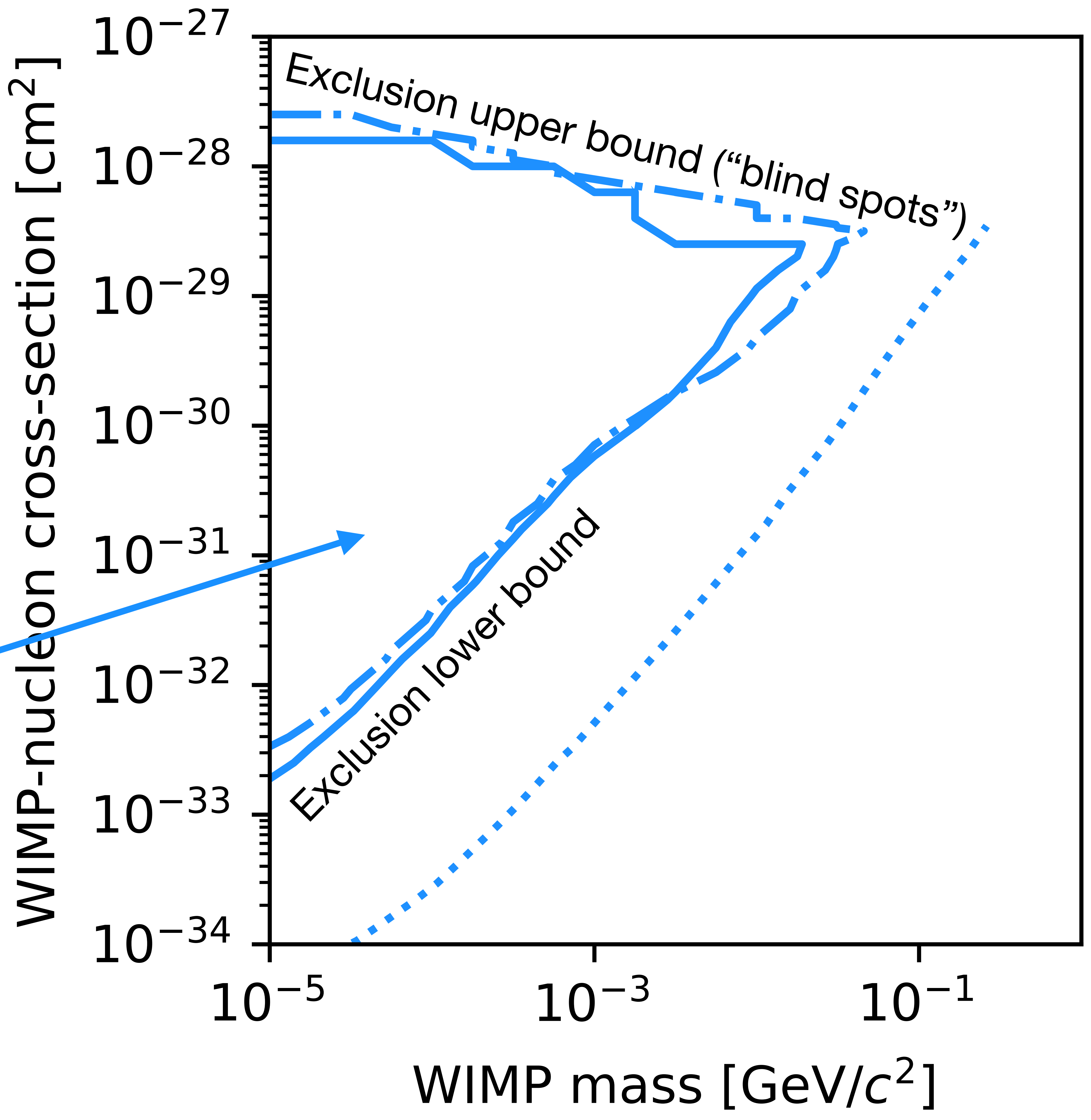
Fast but **ignores detector spectral response information.**

laura.manenti@sydney.edu.au

Exclusion limits in XENON1T

- **Dotted:** previous BBDM study by JW Wang et al. (2021)
- **Dotted-dashed:** simple "recast method" + updated DM profile and corrected detector efficiency
- **Solid:** full detector response included

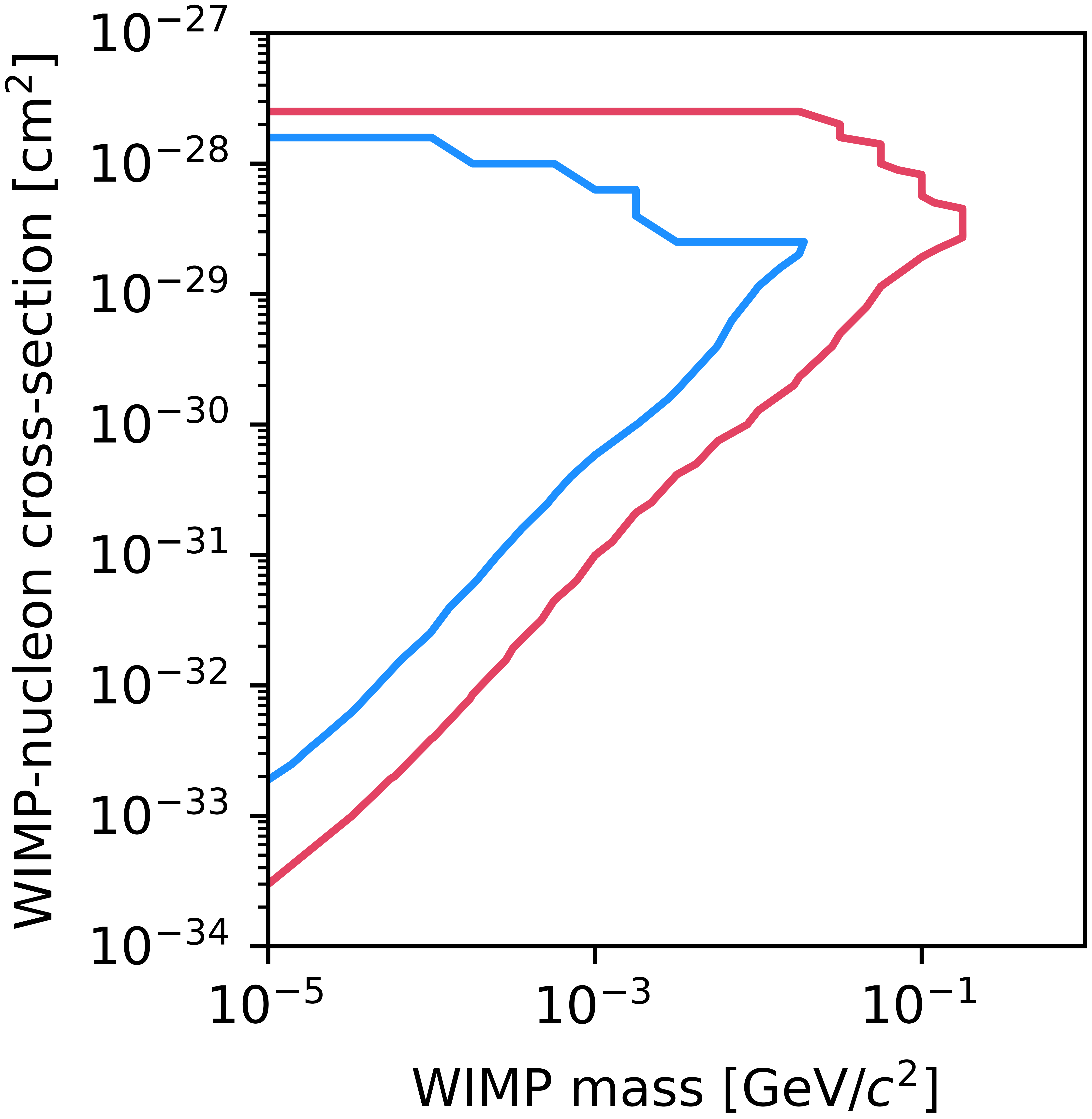
Given what the detector observed (and our model), we can rule out anything within this region at 90% confidence.



laura.manenti@sydney.edu.au

Exclusion limits in XENON1T vs LZ

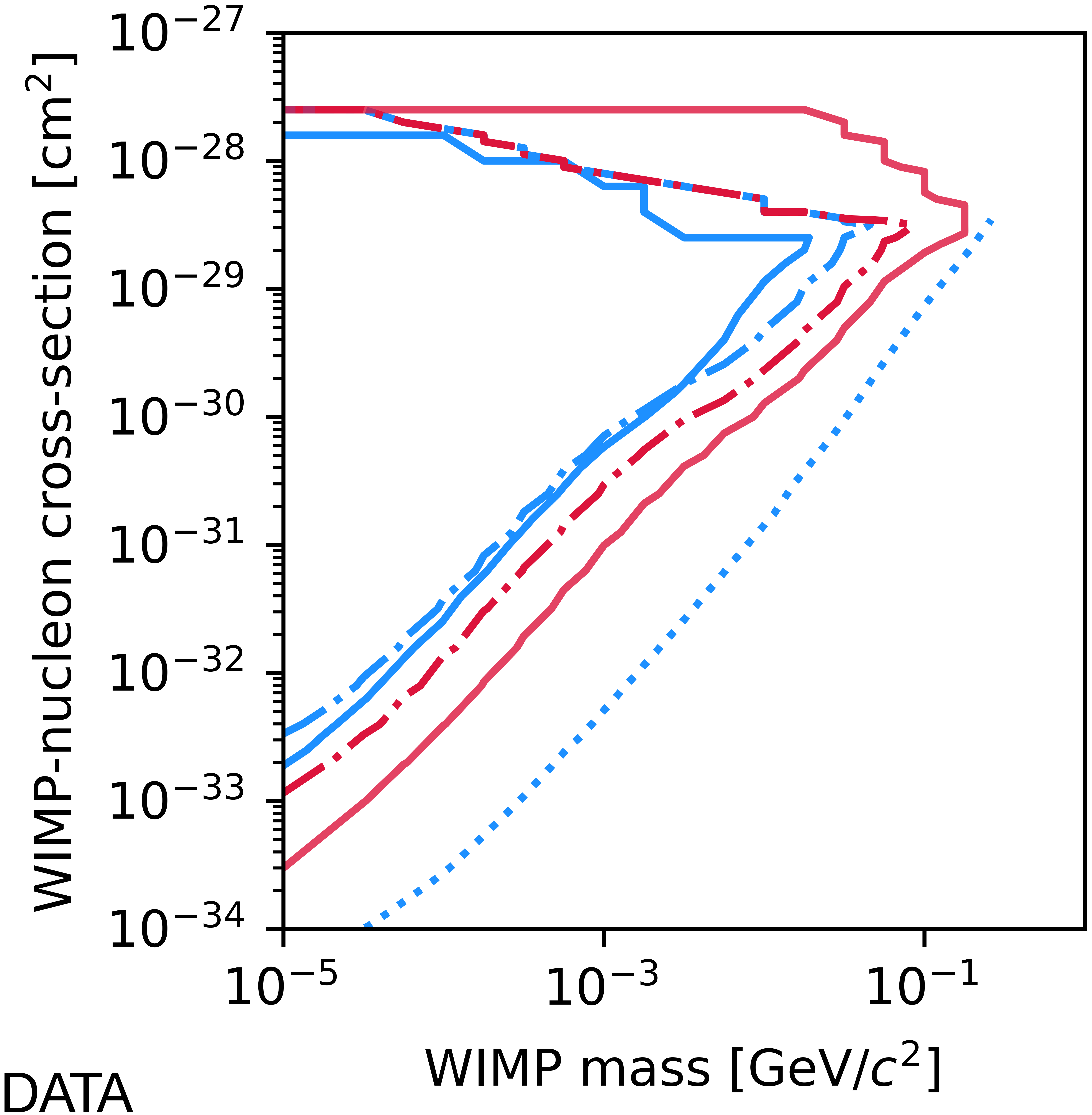
- **Solid red:** LZ - EFT/matching
- **Solid blue:** XENON1T - full detector response included



laura.manenti@sydney.edu.au

All together...

- **Dotted:** XENON1T - previous BBDM study by JW Wang et al. (2021)
- **Dotted-dashed:** XENON1T - simple "recast method" + updated DM profile and corrected detector efficiency
- **Solid:** XENON1T - full detector response included
- **Solid red:** LZ - EFT/matching



ALL PLOTS USE PUBLIC AVAILABLE DATA

The team


Knut Mora and Erin Barillier
ETH - Zurich

Paolo Padovani
ESO - München

Alessanfro Granelli
Università di Bologna


Isaac Sarnoon and Francesco Arneodo
NYU Abu Dhabi

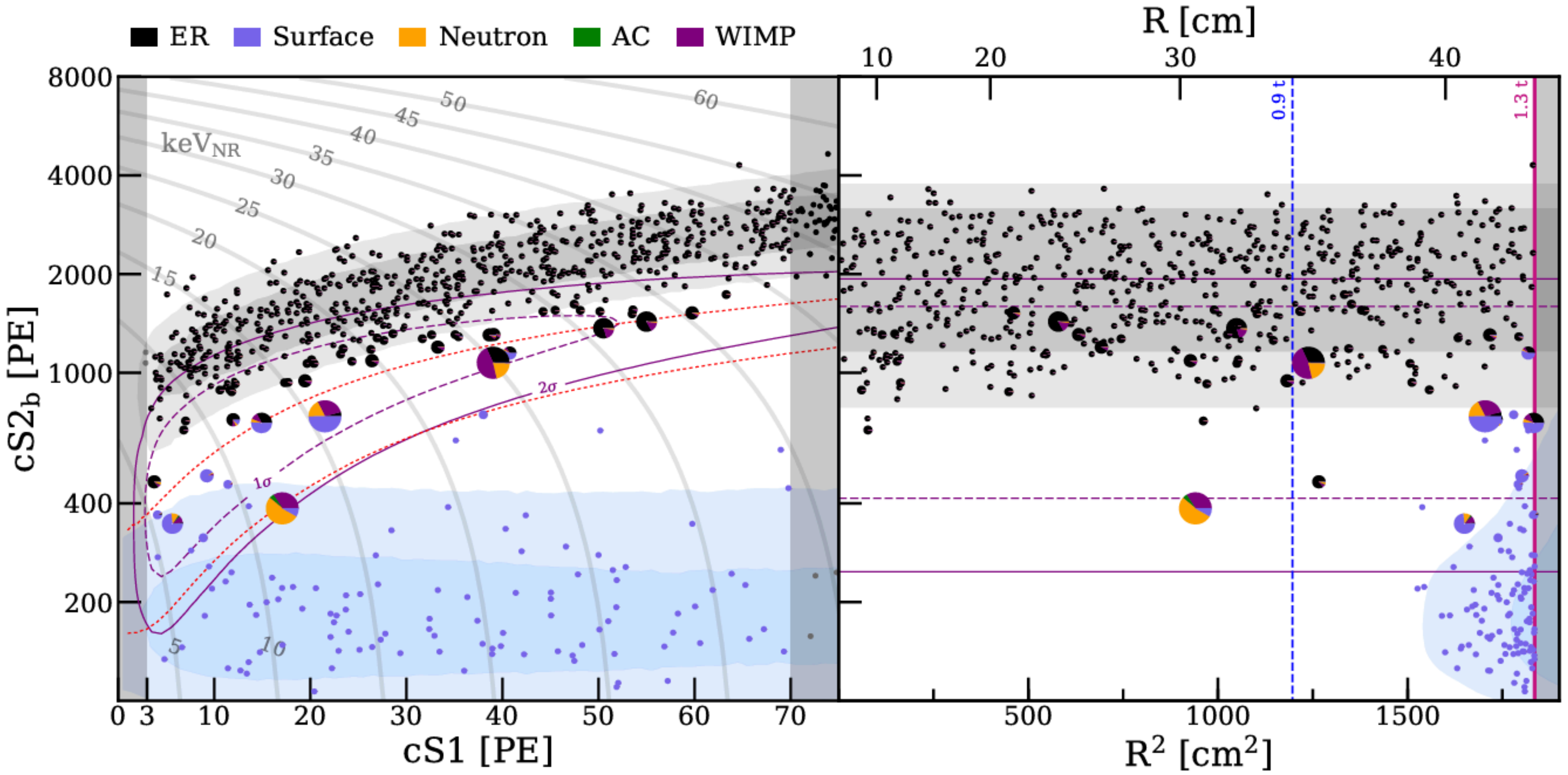
Yongheng Xu
UCLA

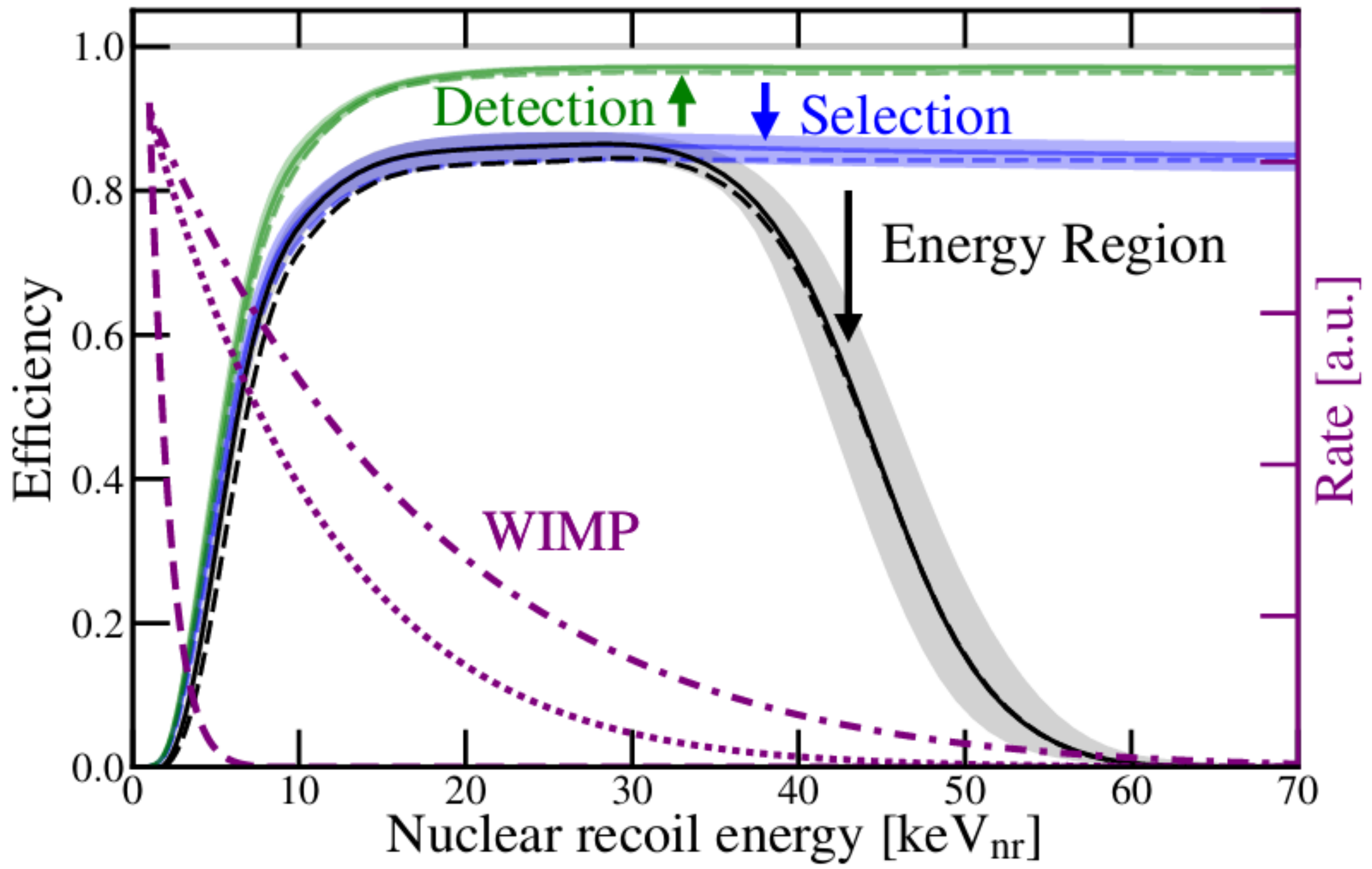
😳 uestions

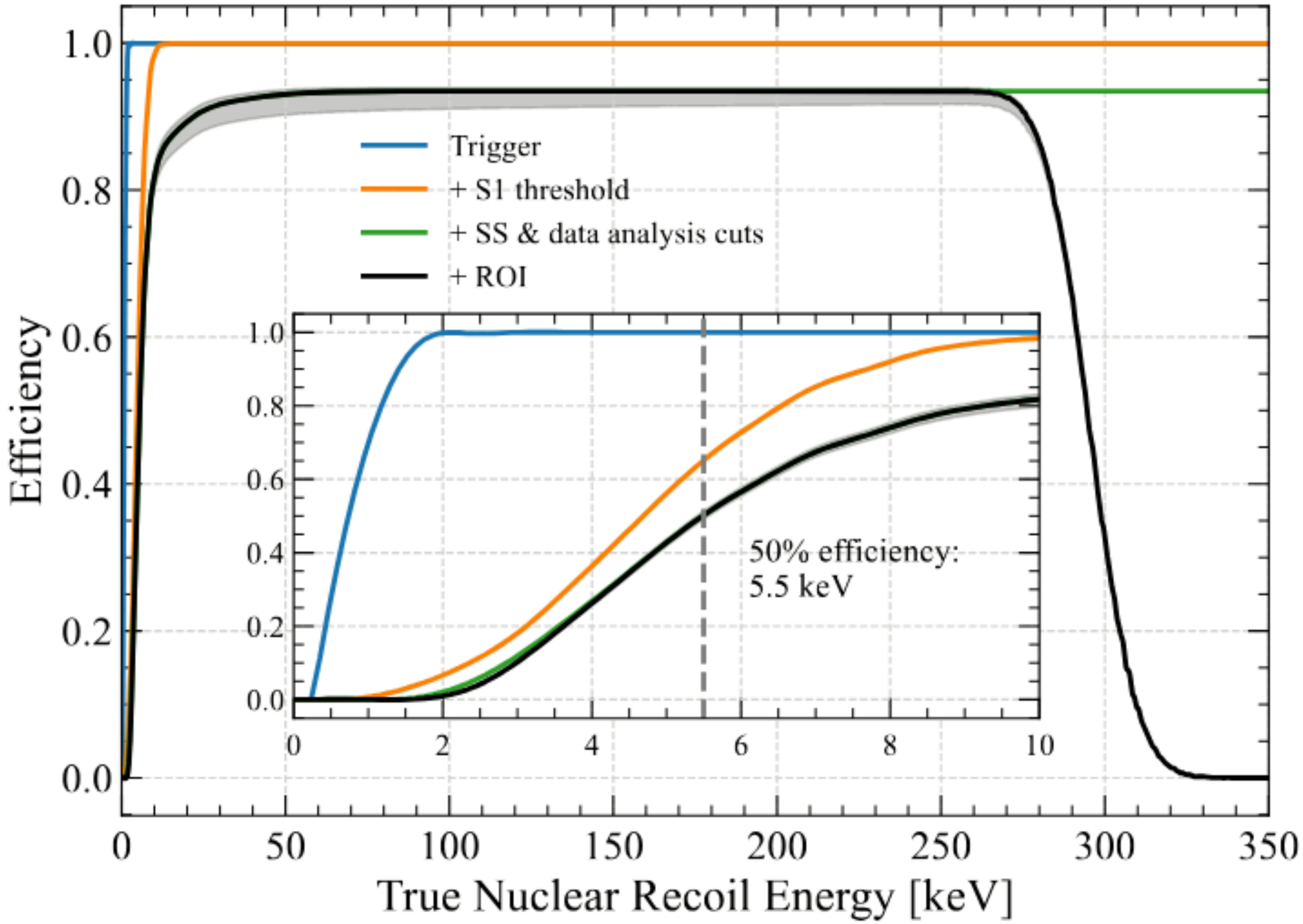
1. Why are your limits generally “worse” than previous works?
2. Why are LZ limits better than XENON?
3. What did you learn?
4. Is BBDM an effective way to search for sub-GeV DM?
5. What's the role of the DM profile in your analysis?
6. When are you going to publish this work?
7. Can you explain again…?

laura.manenti@sydney.edu.au

Backup slides


ER
Surface
Neutron
AC
WIMP
R [cm]
cS2$_b$ [PE]
cS1 [PE]
R^2 [cm^2]
keV$_{NR}$
0.9 t
1.3 t


Detection
Selection
Energy Region
WIMP
Efficiency
Rate [a.u.]
Nuclear recoil energy [keV$_{nr}$]



Trigger
+ S1 threshold
+ SS & data analysis cuts
+ ROI
50% efficiency:
5.5 keV
Efficiency
True Nuclear Recoil Energy [keV]
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
250
300
350
0
2
4
6
8
10