Dark Matter – A Particle Physicist's Perspective

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- Swiss astronomer – Fritz Zwicky
- Used virial theorem to calculate mass of galaxy

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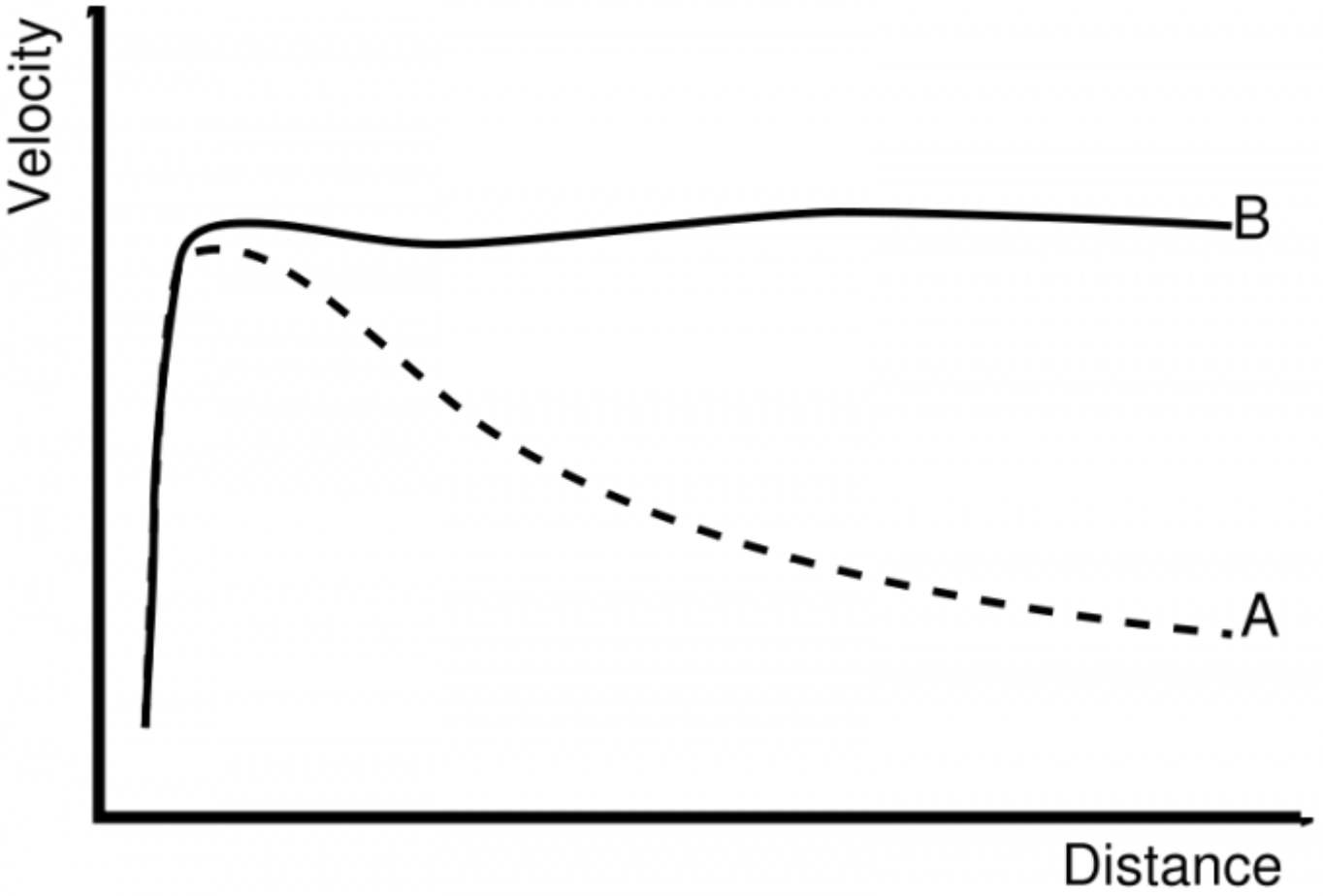
- Factor of 500 different to expected result

Why do we need dark matter?

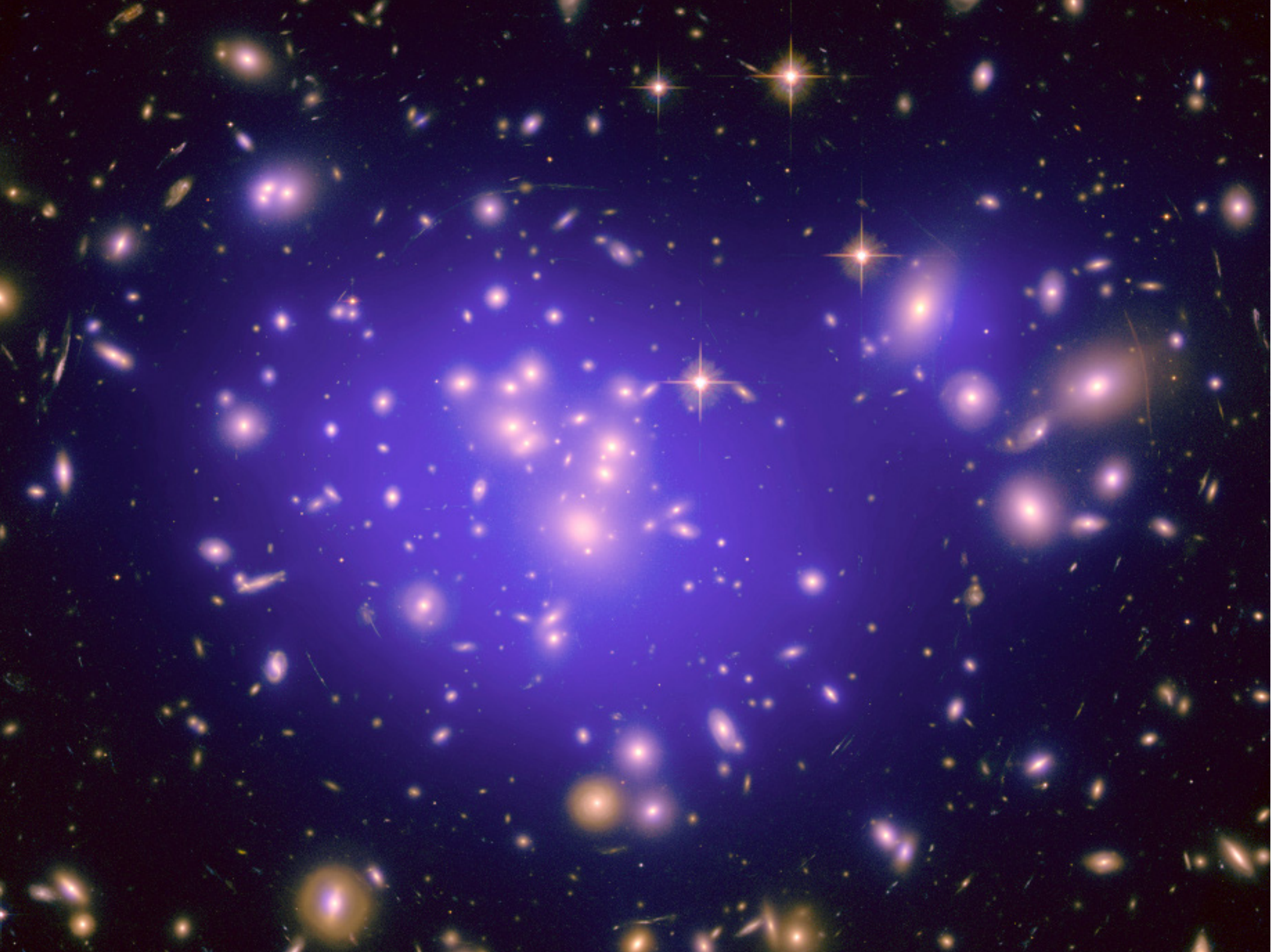
- Rotation curves – how fast stars orbit depends on how far out they are
- First accurate measurement by Vera Rubin – 1970s
- Should fall off – but instead to flatten out

Why do we need dark matter?



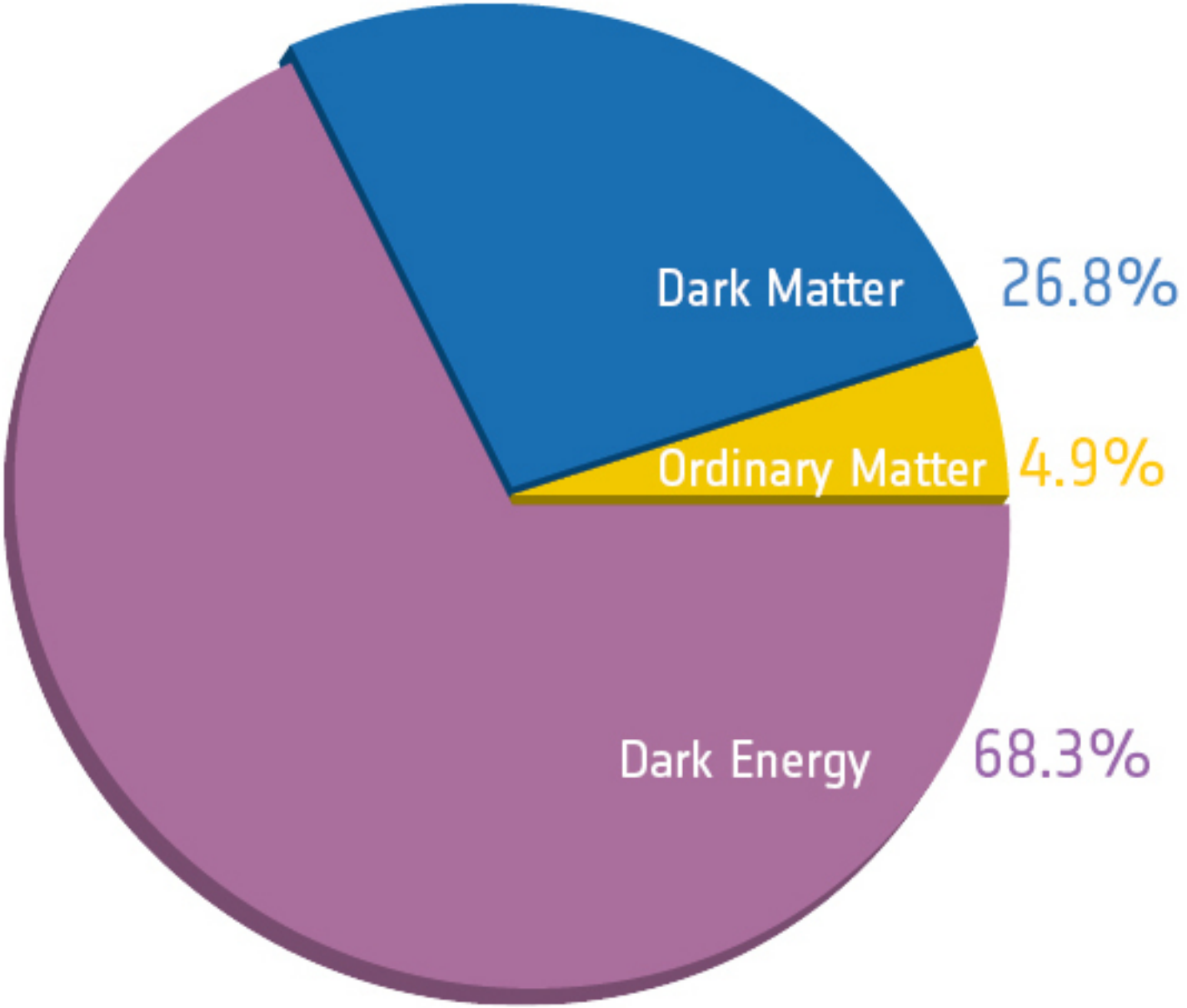
Why do we need dark matter?

- Gravitational lensing
  - Similar idea as virial theorem
  - Gravity bends light passing near galaxy – how much depends on how heavy the galaxy is
  - Get a difference between what is seen and the amount calculated



What do we know?

- Cosmic Microwave Background – Plank and WMAP
- Dark Matter is around 26% of universe


Dark Matter
26.8%
Ordinary Matter
4.9%
Dark Energy
68.3%

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- Excess of photons from the centre of the galaxy

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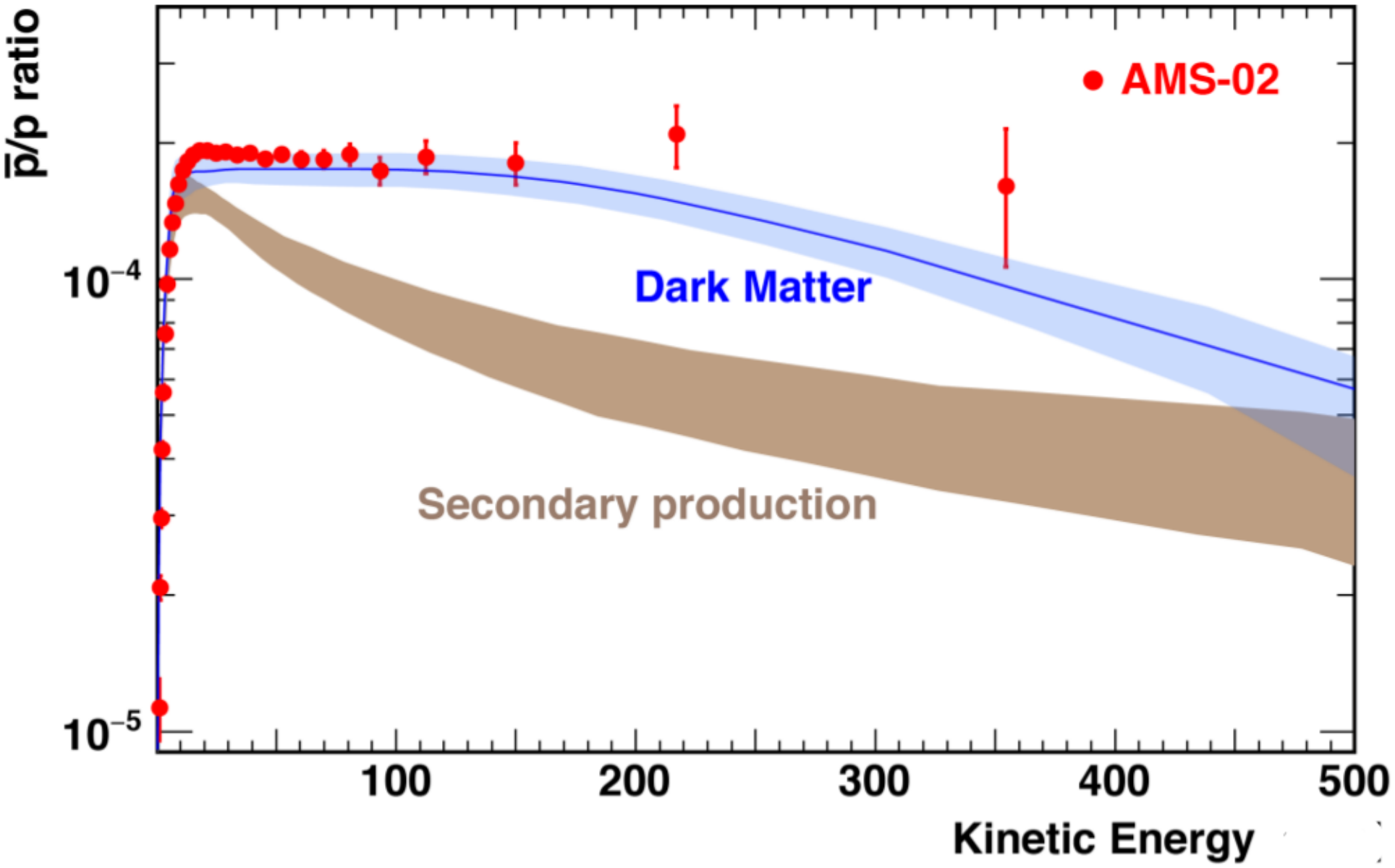
- Excess of antiprotons compared to protons


$\bar{p}/p$ ratio
AMS-02
Dark Matter
Secondary production
10^{-4}
10^{-5}
100
200
300
400
500
Kinetic Energy

What else have we seen?

- Excess of photons from the centre of the galaxy
- Excess of antiprotons compared to protons
- Excess of positrons

What haven't we seen?

- Any “real” evidence down here on Earth!

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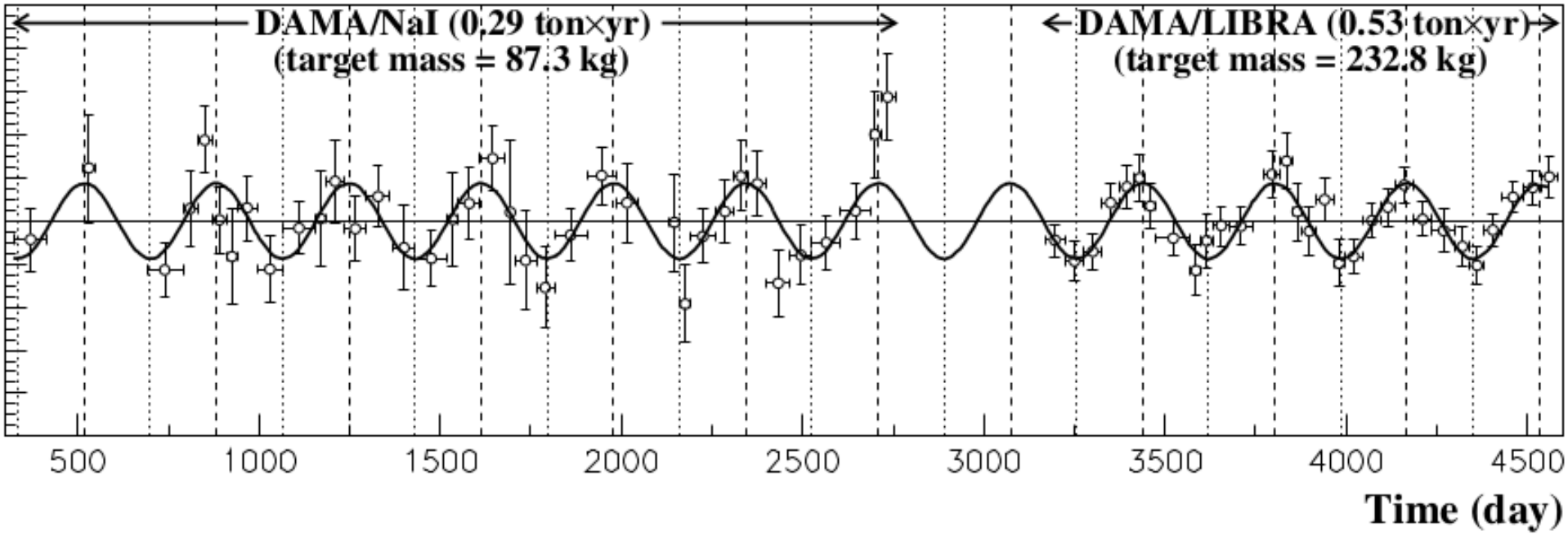
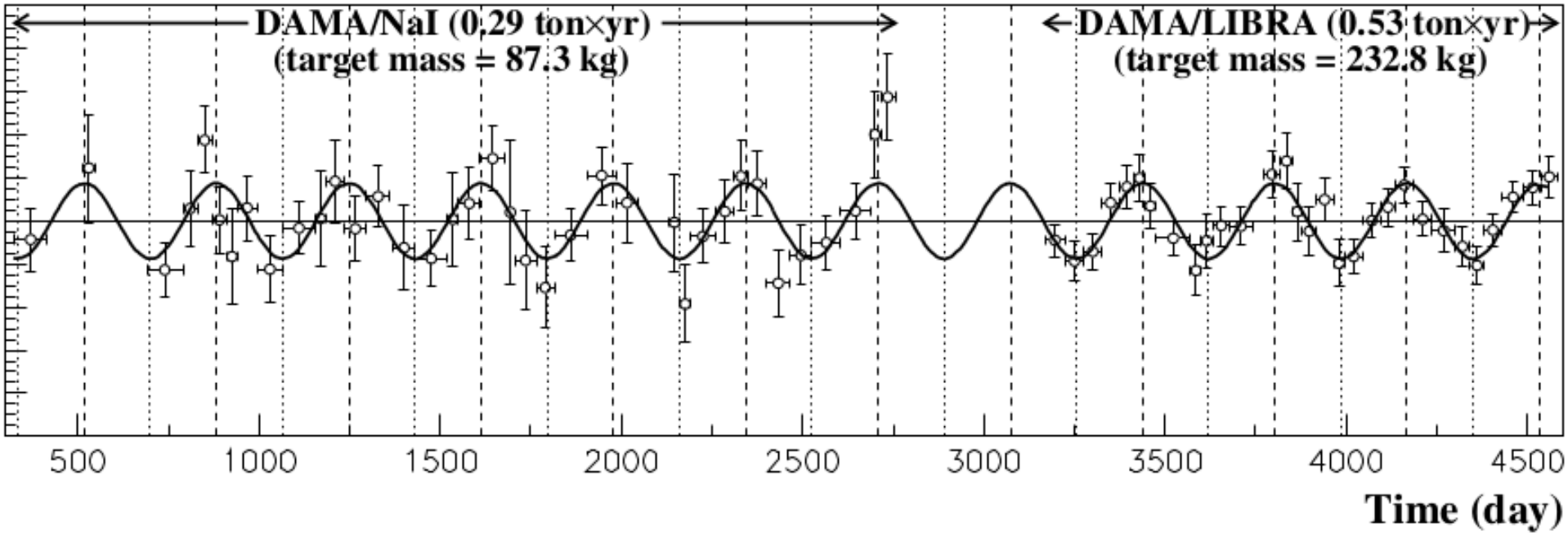
What haven't we seen?

- Any “real” evidence down here on Earth!
- Direct detection limits keep on going down
- Except something odd perhaps in
  - DAMA
  - CoGeNT
  - CDMS


DAMA/NaI (0.29 ton×yr)
(target mass = 87.3 kg)
DAMA/LIBRA (0.53 ton×yr)
(target mass = 232.8 kg)
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (day)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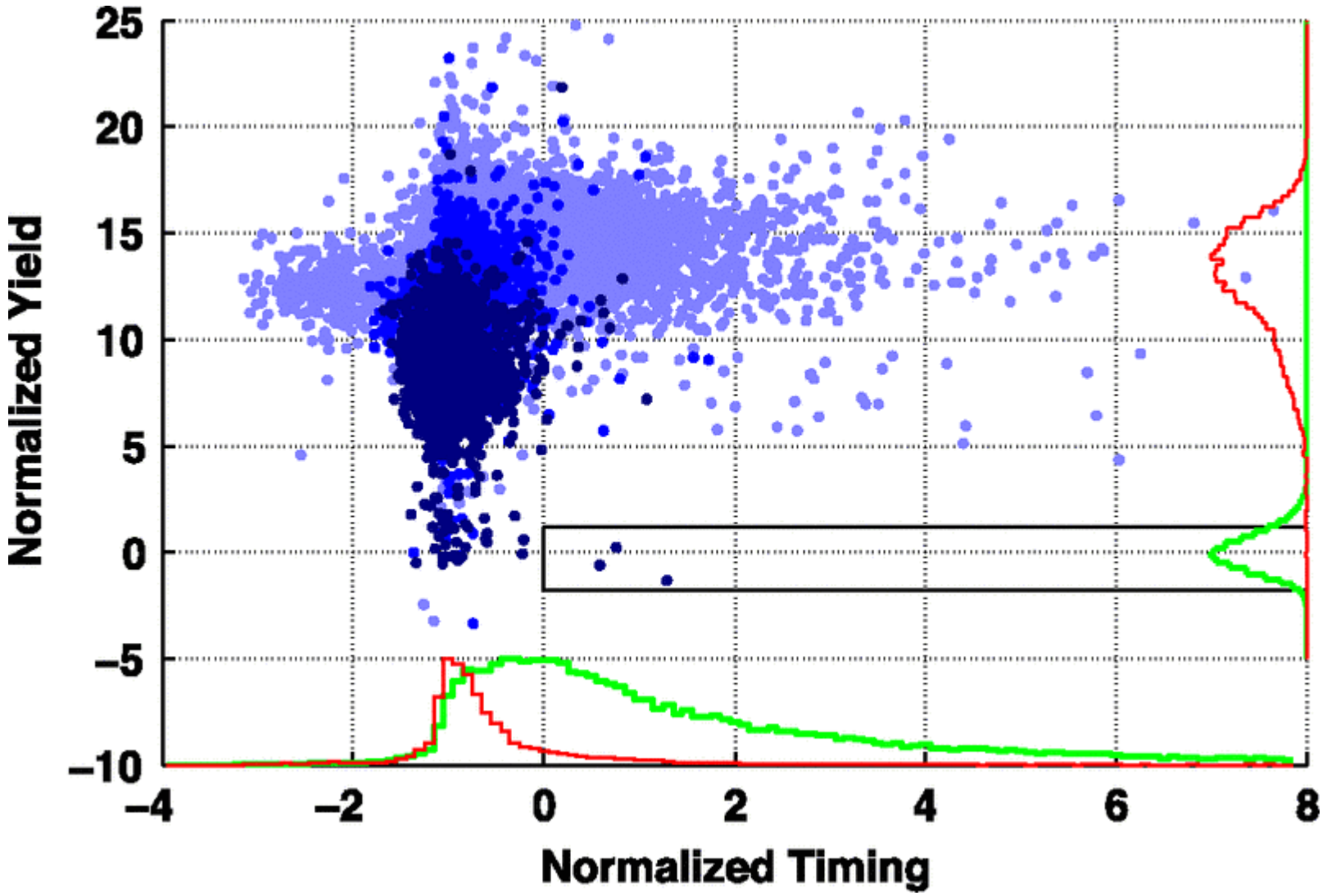
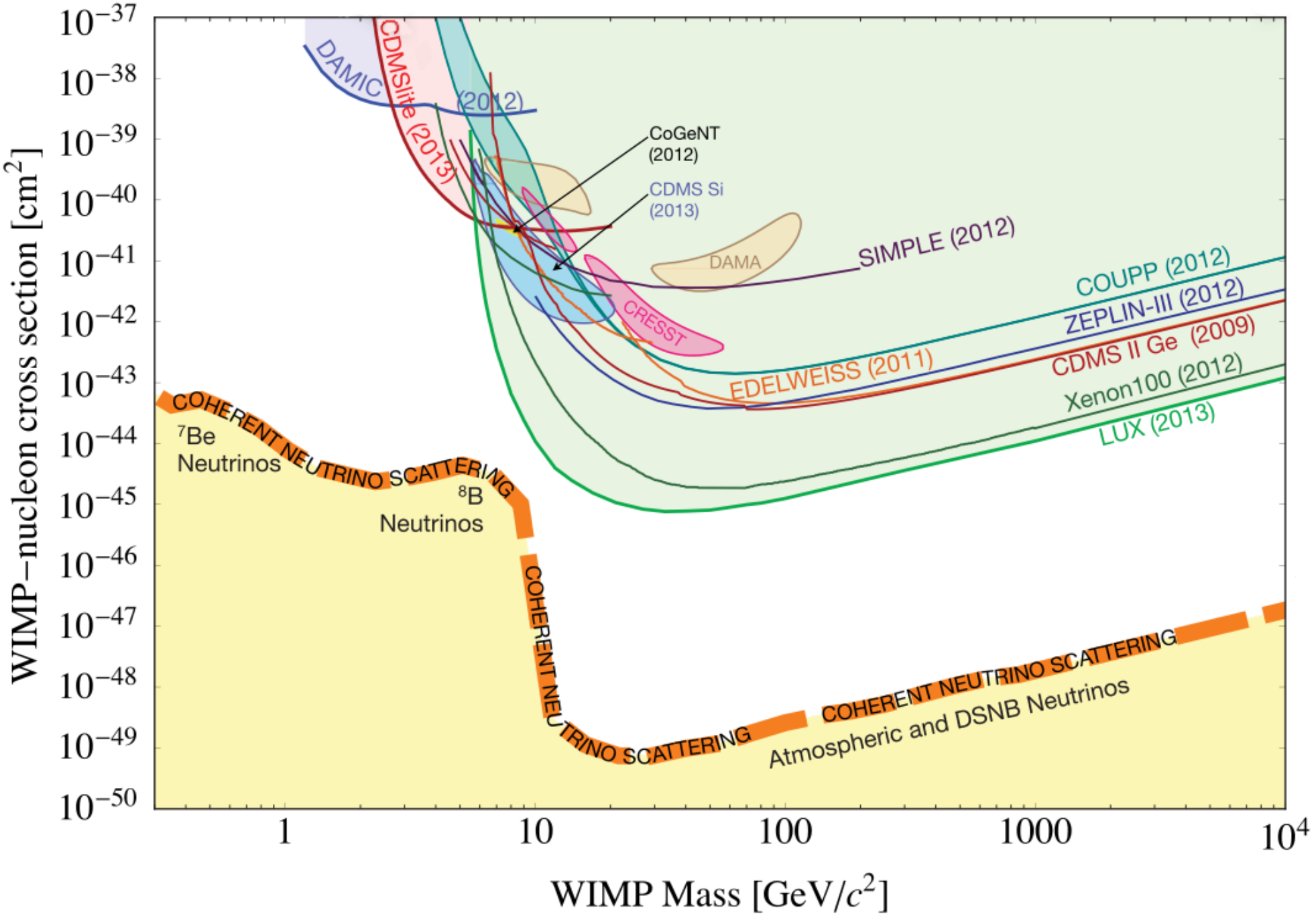

Normalized Yield
25
20
15
10
5
0
−5
−10
−4
−2
0
2
4
6
8
Normalized Timing


WIMP−nucleon cross section [cm^2]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
1
10
100
1000
10^4
WIMP Mass [GeV/c^2]
DAMIC
CDMSlite (2013)
(2012)
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
Xenon100 (2012)
LUX (2013)
COHERENT NEUTRINO SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
COHERENT NEUTRINO SCATTERING
COHERENT NEUTRINO SCATTERING
Atmospheric and DSNB Neutrinos

What am I doing?

What am I doing?

- Looking at simplified models
  - Single dark matter particle, single mediator particle

What am I doing?

- Expect “new physics” to affect lots of “old physics”
- What we haven't seen can be just as useful as what we have

Thanks!

Backup slides

What else have we seen?

- Excess of photons from the centre of the galaxy
- Excess of antiprotons compared to protons
- Excess of positrons
- Hints of self interaction between dark matter particles?