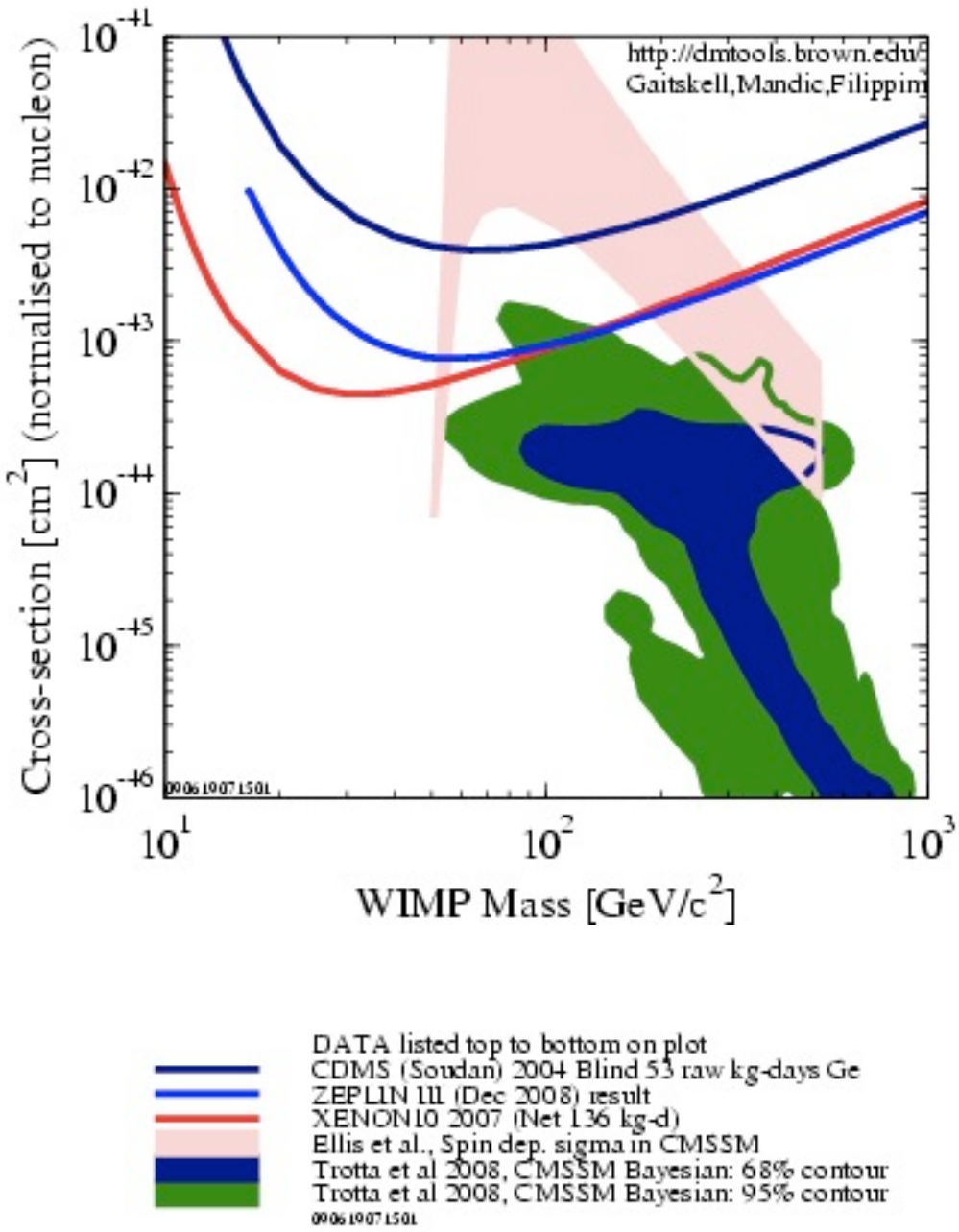
Dark Matter Detection and Dynamical Systematics

Homework due next time

PLEASE EVALUATE THE COURSE

Particle physicists' best guess is that the **Cold Dark Matter** needed in cosmology is a new form of fundamental particle called the **WIMP** (Weakly Interacting Massive Particle). There are ambitious projects to detect WIMPS in underground laboratories, like CDMS:

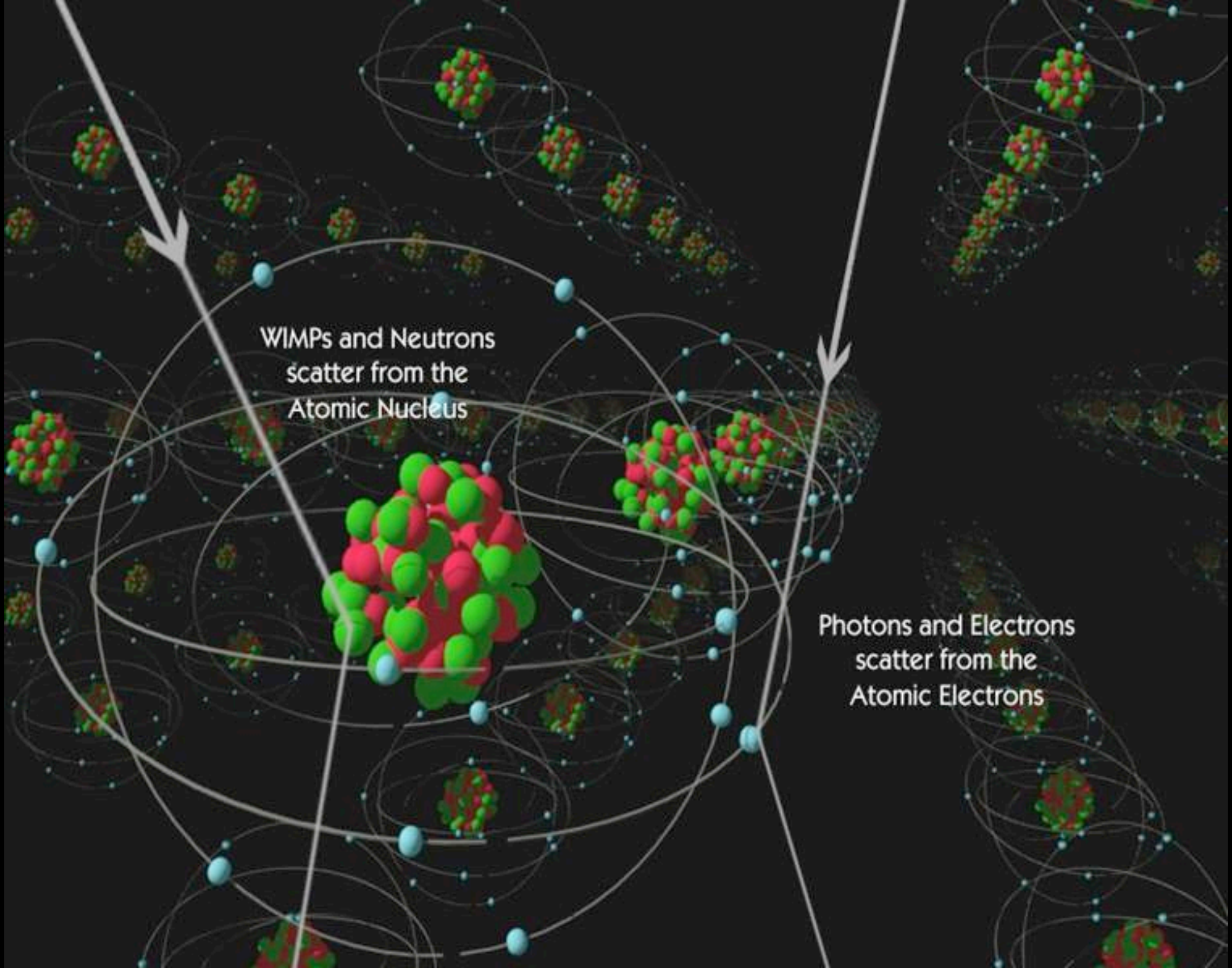


Experimental approaches

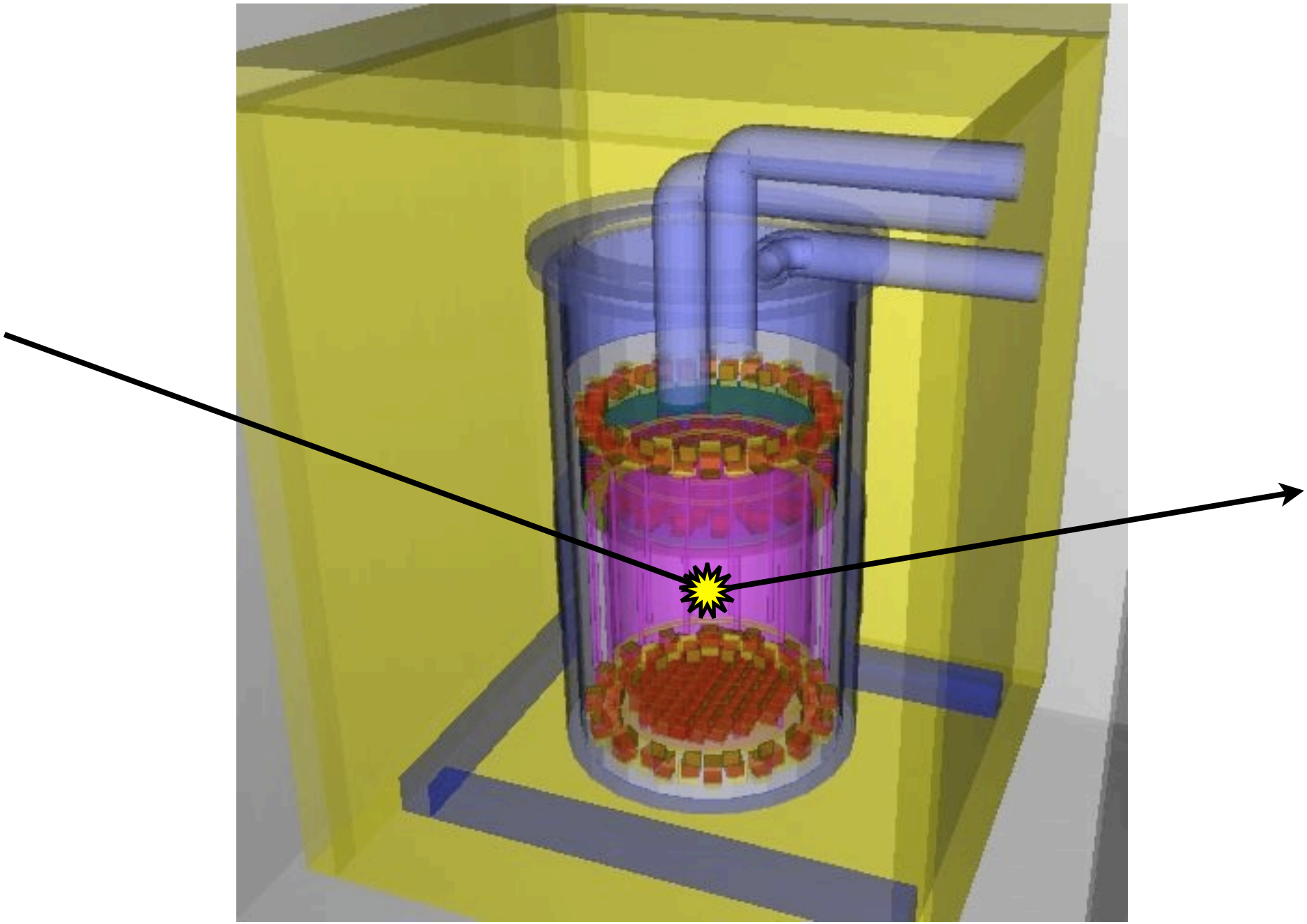
- Direct detection
  - Weak interactions with target nuclei
  - e.g., Germanium (CDMS), Xenon
- Indirect detection
  - Gamma rays from self-annihilation
  - Excess cosmic rays from WIMPs
- Production in particle accelerators
  - Missing Energy from LHC experiments
  - Must find Higgs!

Direct Detection

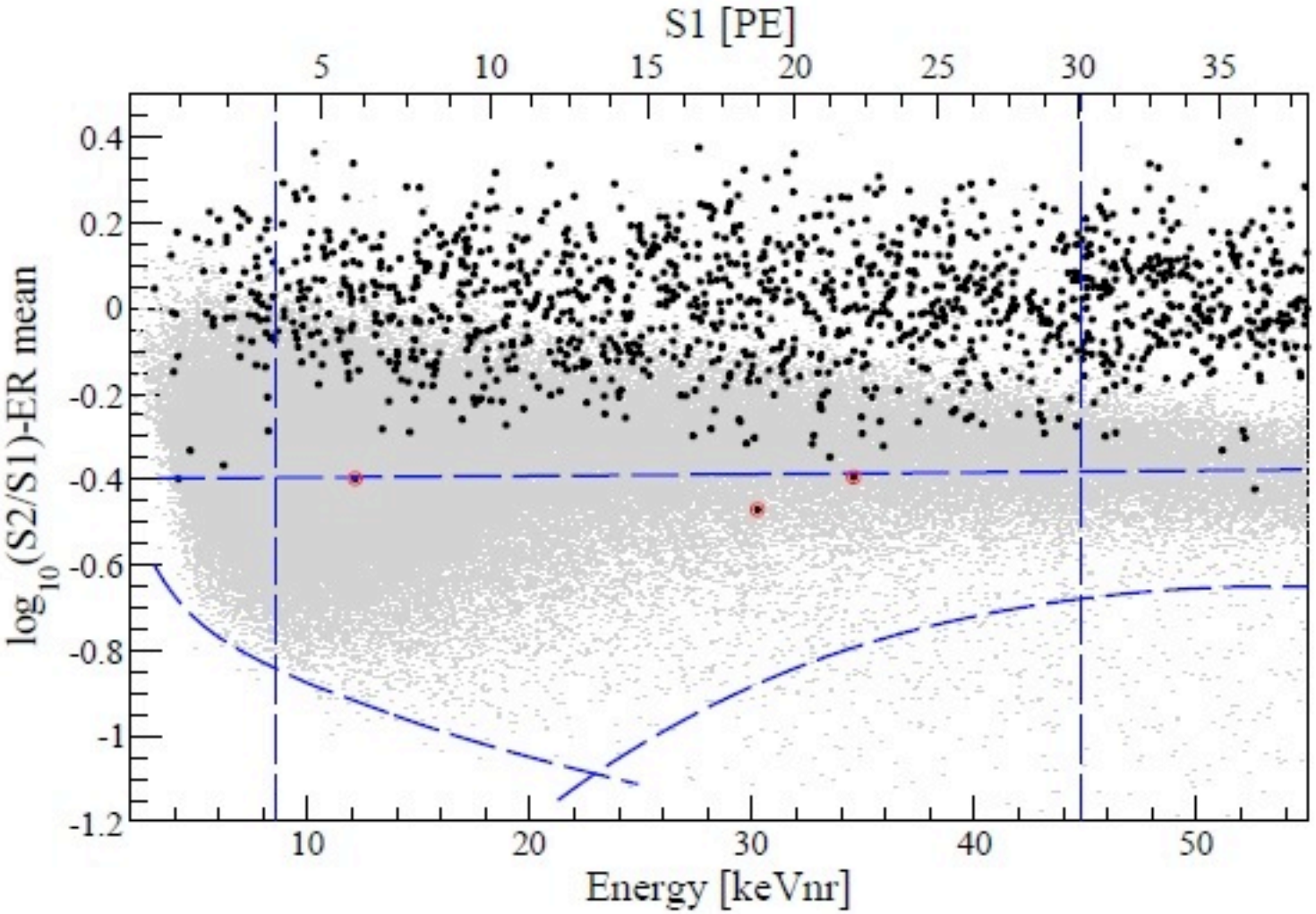
- Very rarely, WIMPs will interact with atomic nuclei via the weak interaction
  - Look for extra energy deposited in Germanium lattice (e.g., CDMS)
  - or ionization caused by the passage of WIMPs (e.g., XENON100)
- Backgrounds a big challenge: cosmic rays, native radioactivity, +lots of other things can mimic a WIMP signal


WIMPs and Neutrons
scatter from the
Atomic Nucleus
Photons and Electrons
scatter from the
Atomic Electrons

Xenon100 experiment

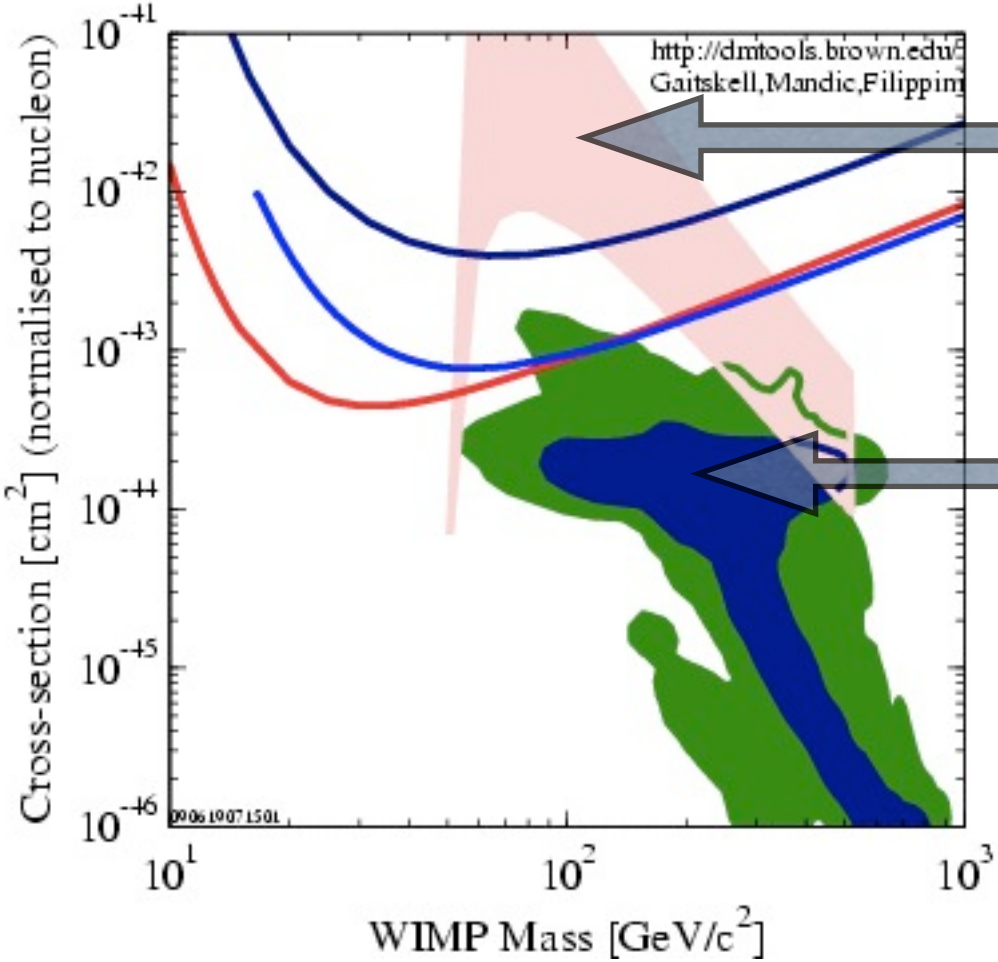


Xenon100 events



electron recoils (uninteresting)

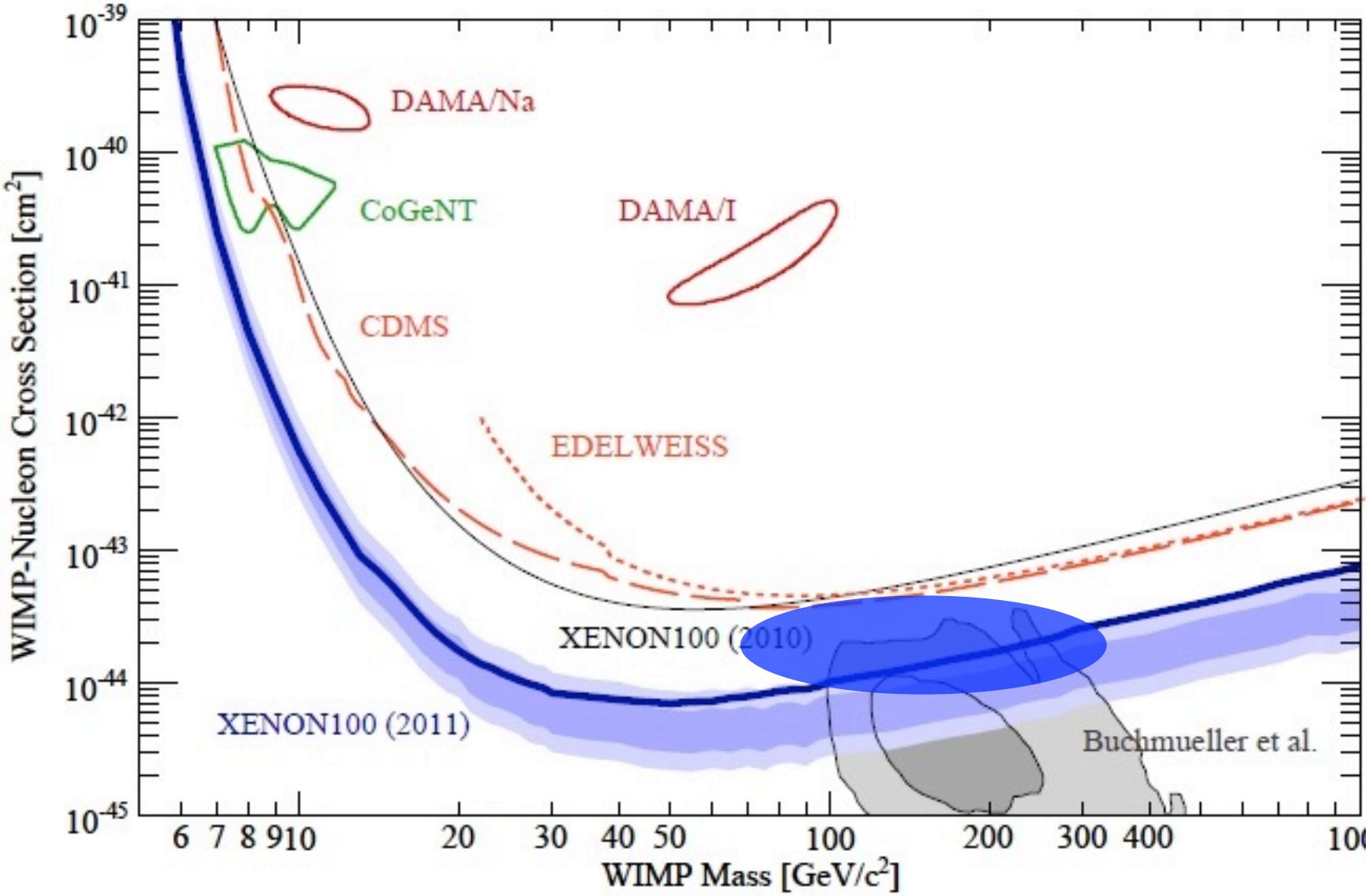
nuclear recoils (where WIMP signal should be)



original prediction

current expectation

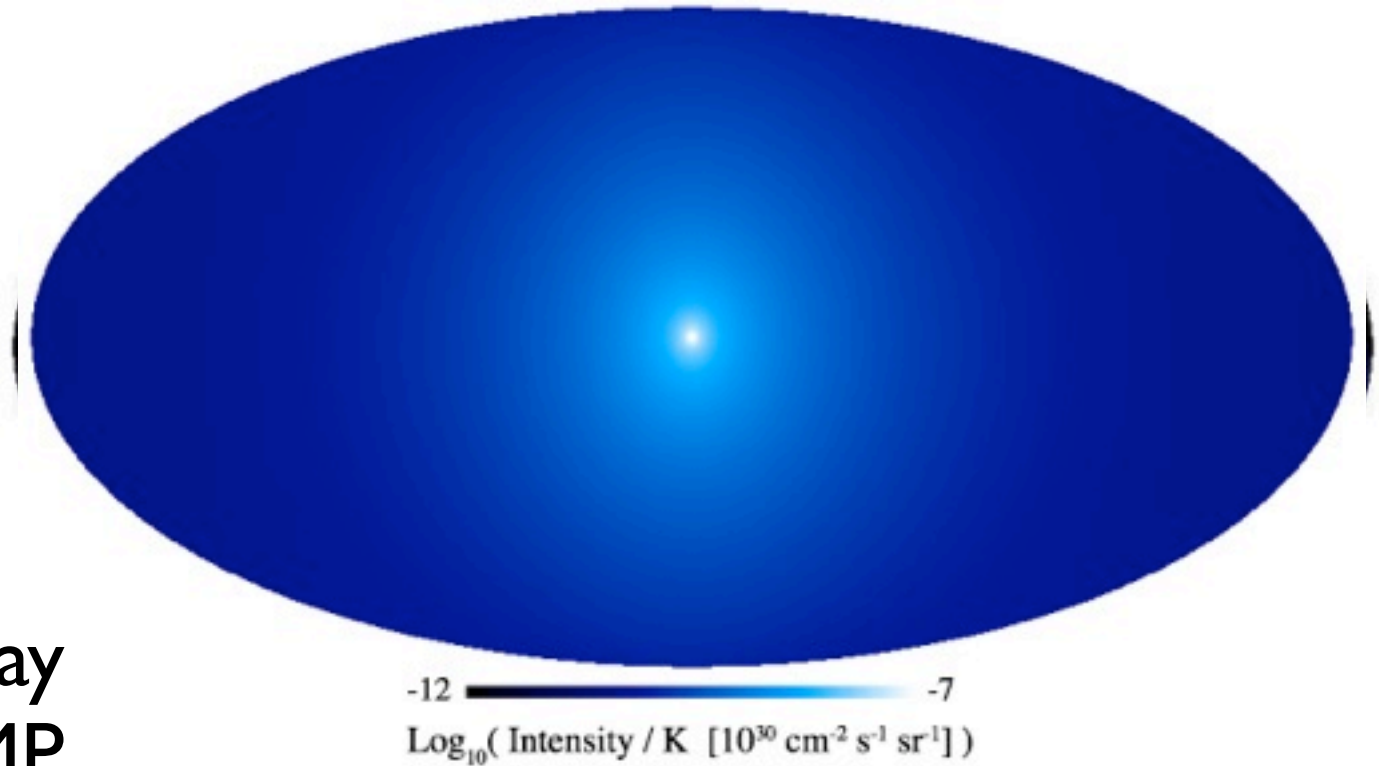
DATA listed top to bottom on plot
CDMS (Soudan) 2004 Blind 53 raw kg-days Ge
ZEPLIN III (Dec 2008) result
XENON10 2007 (Net 136 kg-d)
Ellis et al., Spin dep. sigma in CMSSM
Trotta et al 2008, CMSSM Bayesian: 68% contour
Trotta et al 2008, CMSSM Bayesian: 95% contour
0906.1907-1501

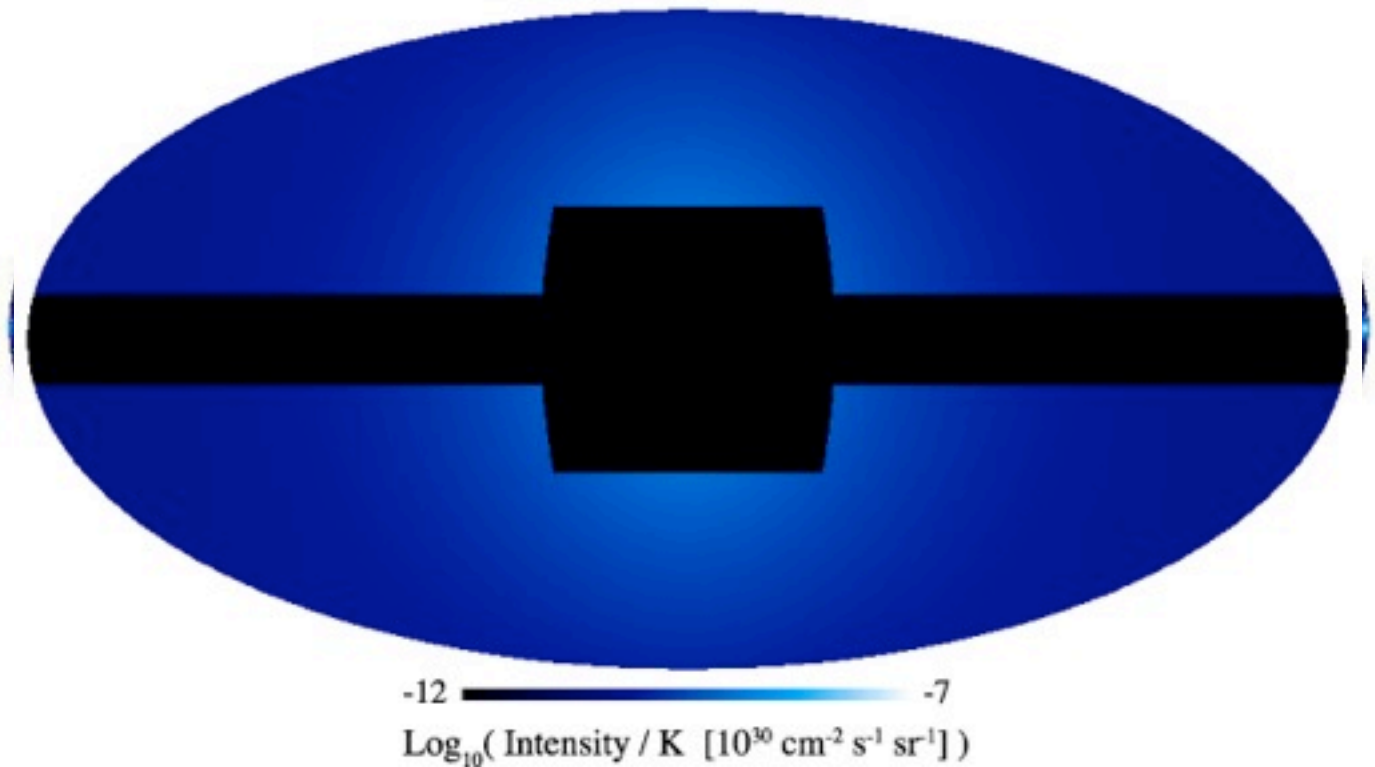

DAMA/Na
CoGeNT
DAMA/I
CDMS
EDELWEISS
XENON100 (2010)
XENON100 (2011)
Buchmueller et al.
WIMP-Nucleon Cross Section [cm^2]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
6 7 8 9 10 20 30 40 50 100 200 300 400

Indirect Detection

- WIMPs are their own antiparticles
  - Should sometimes meet and annihilate
- WIMPs annihilate into standard model particles
  - Should produce gamma rays and maybe cosmic rays

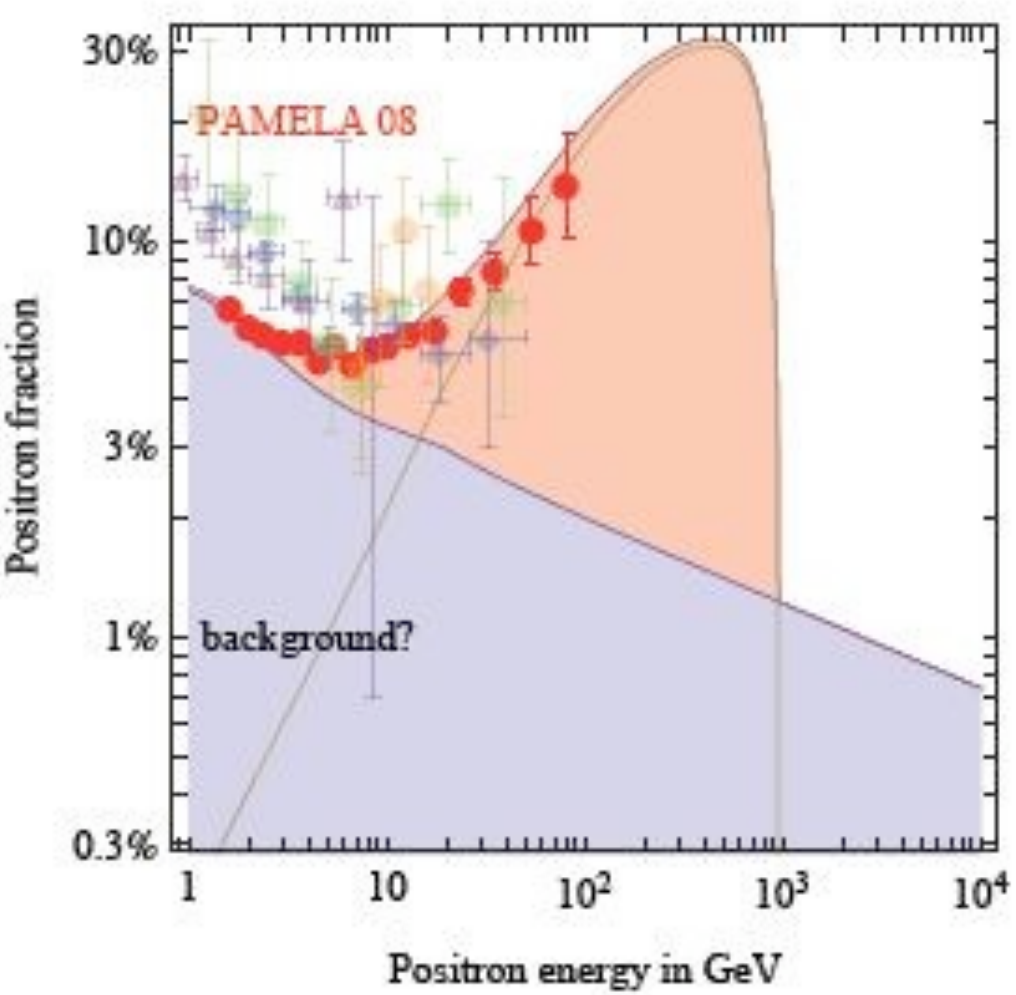
Predicted gamma ray emission from WIMP annihilations in Galactic halo.



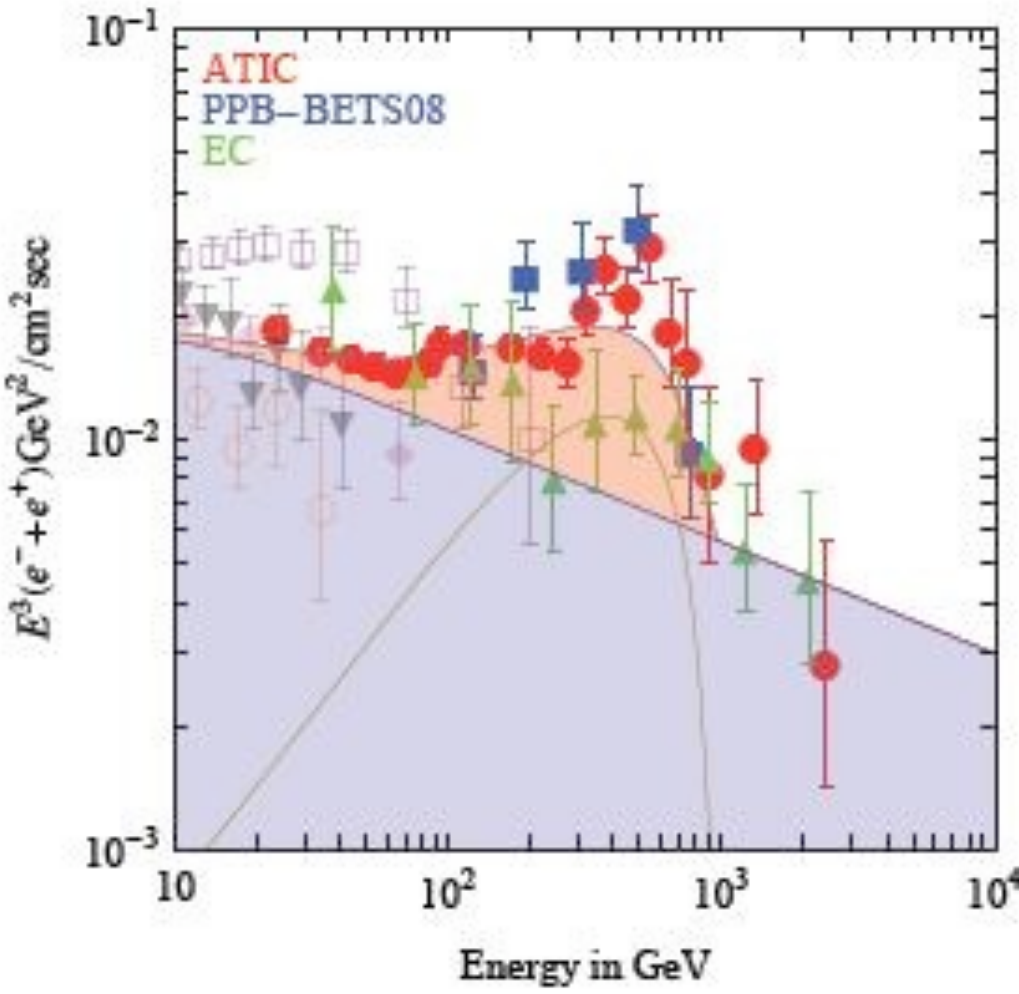


Cosmic Ray Experiments

2009: PAMELA

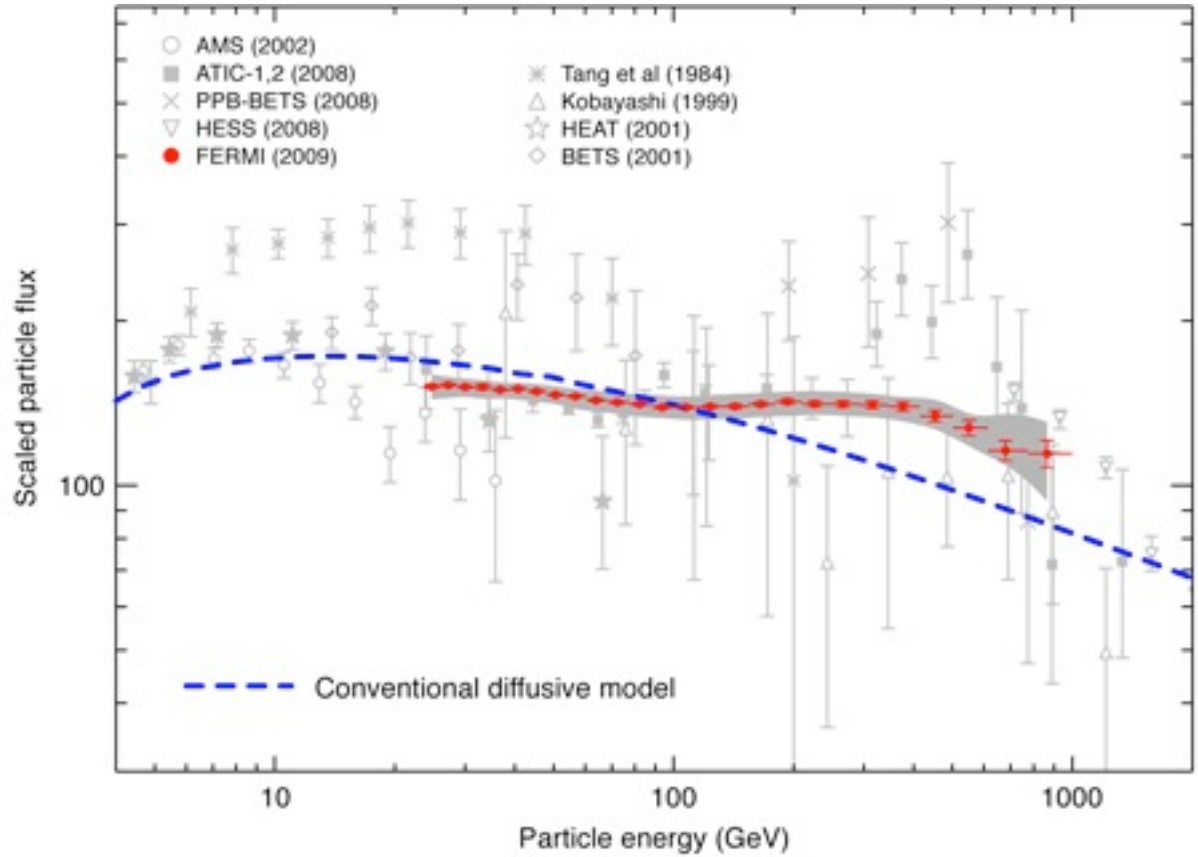


ATIC



Excess (in orange) possibly due to dark matter

2011: FERMI



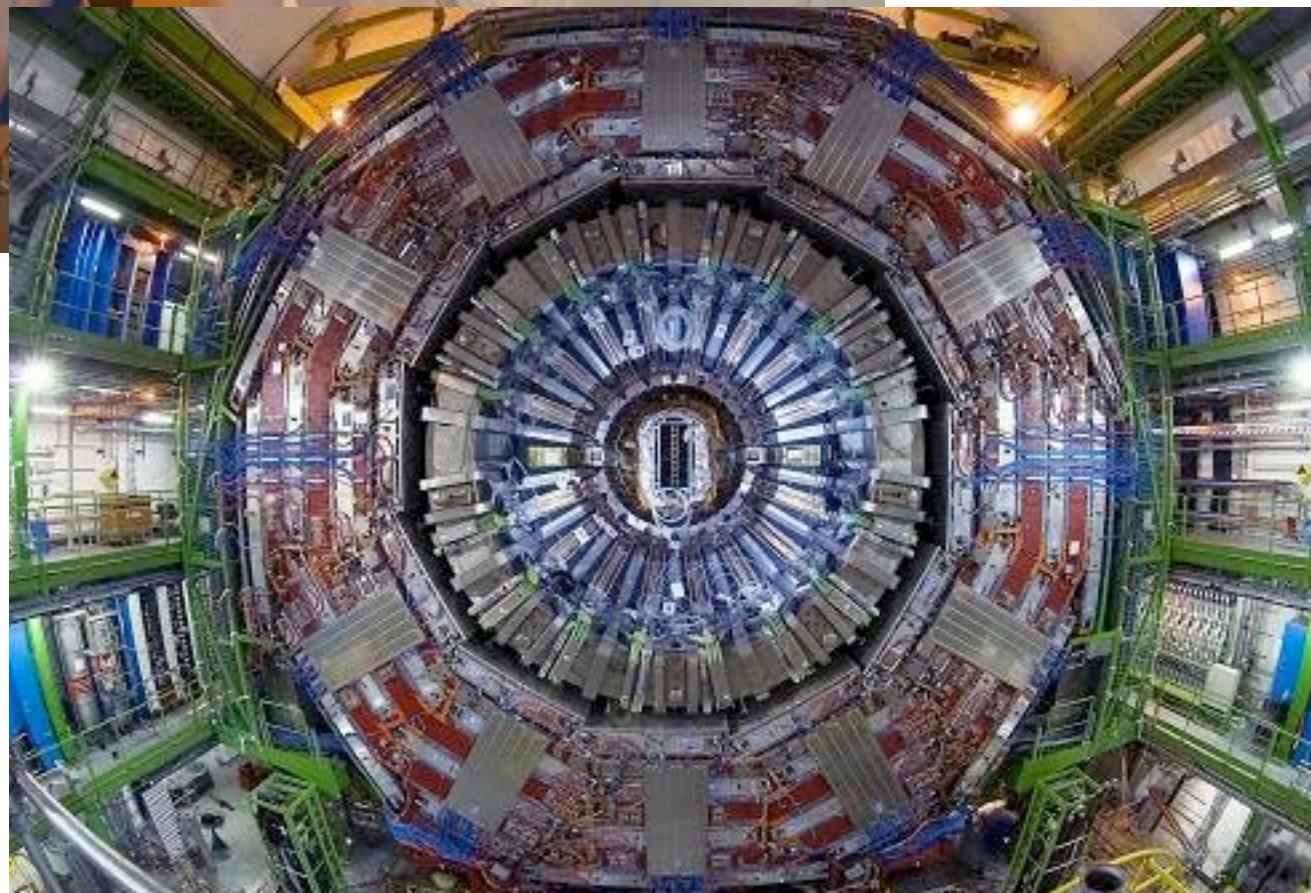
Excess went away.

No dark matter signal, just astrophysical sources.

Accelerators

- Finding the Higgs particle is a necessary but not sufficient condition for the existence of WIMPS
- The LHC will reach energies sufficient to potentially create WIMPs in high energy collisions
  - The signal would be apparent non-conservation of mass-energy as the WIMP leaves the detector unrecorded

LHC

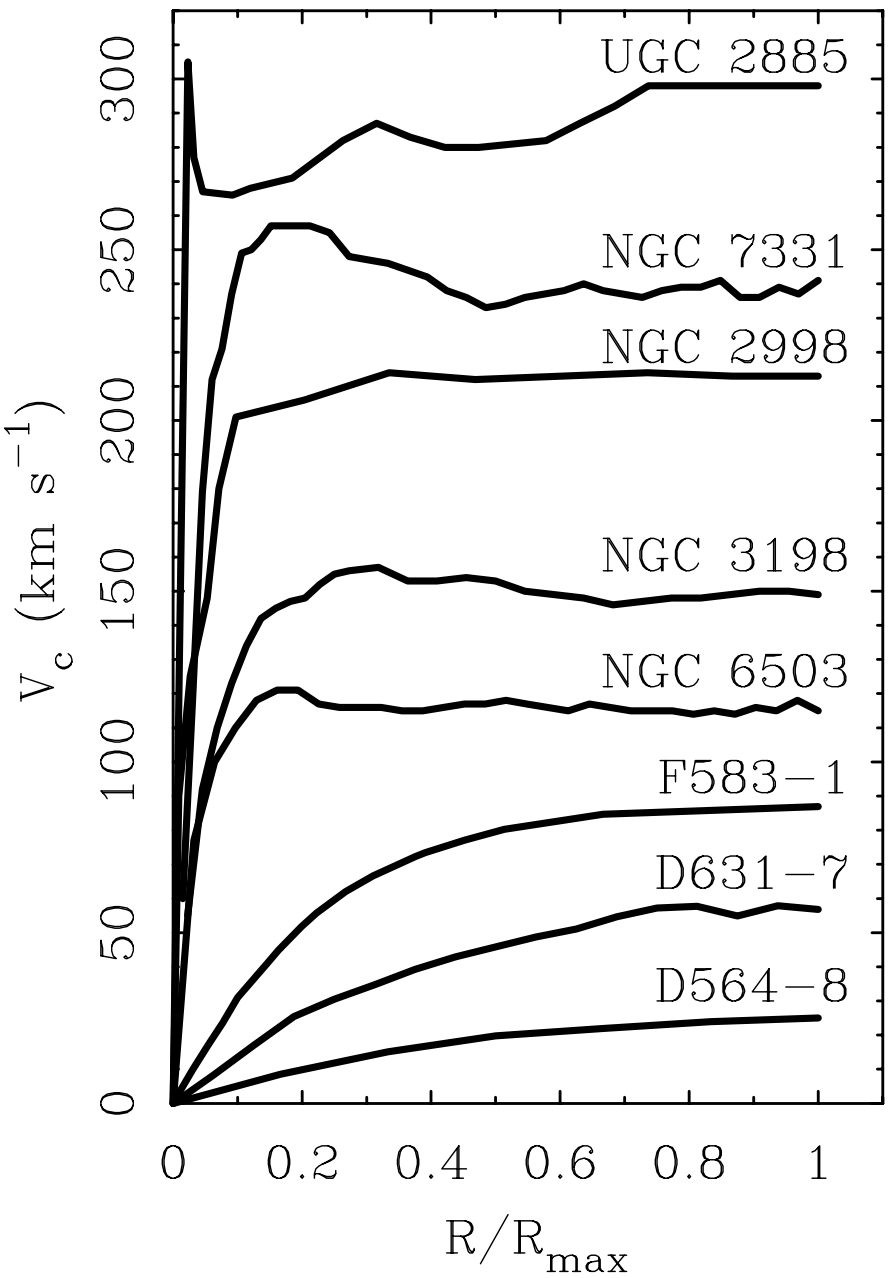


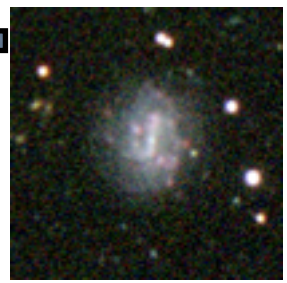
ATLAS
experiment

Dynamical Systematics

- Rotation curves roughly flat at large radius
- Inner RC well predicted by "maximum disk"
- Disk-halo "conspiracy"
- Tully-Fisher: $L \sim V^4$
- Rotation curve shape depends on light
- Mass Discrepancy-Acceleration relation

Rotation curves flat at large radius

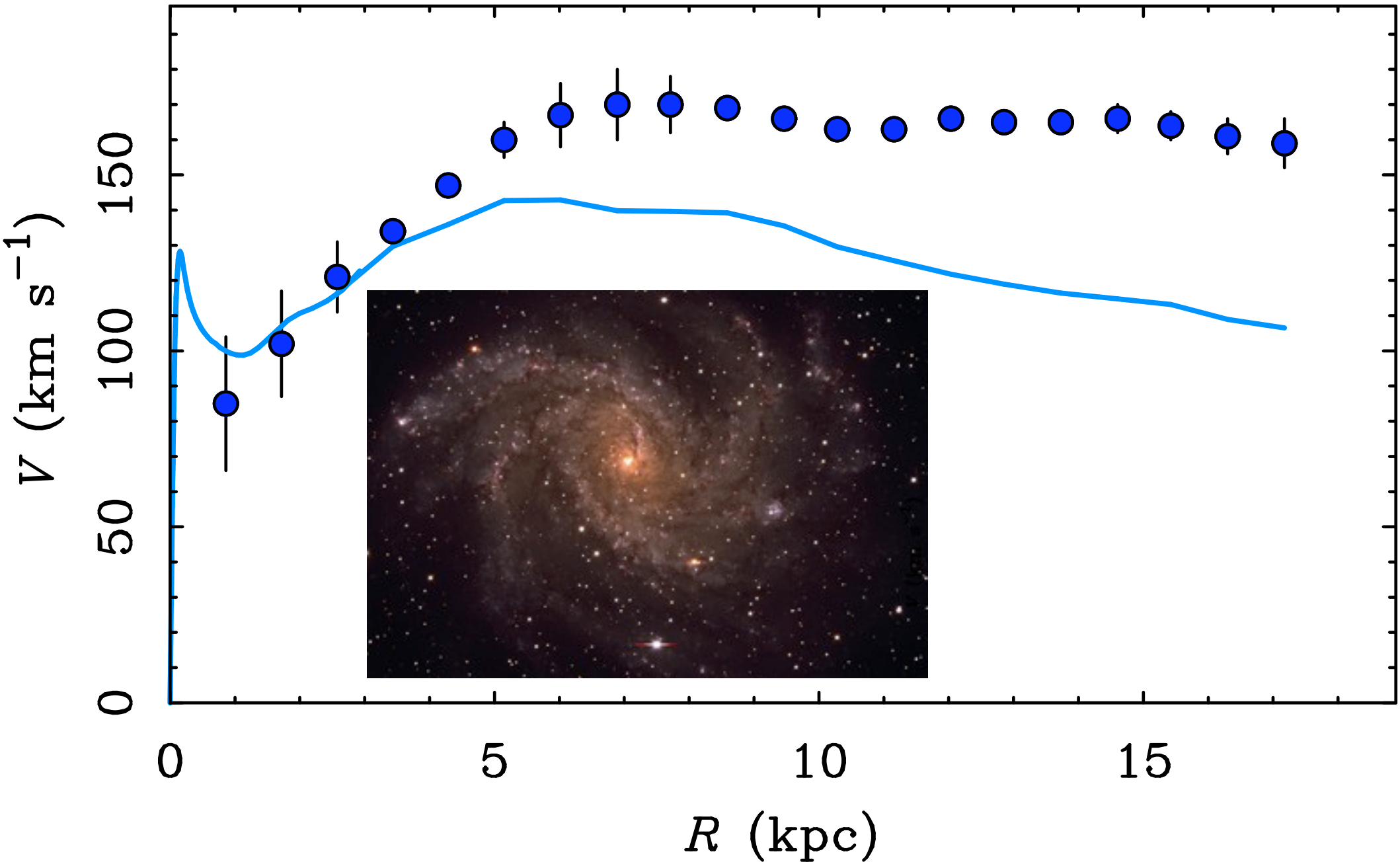




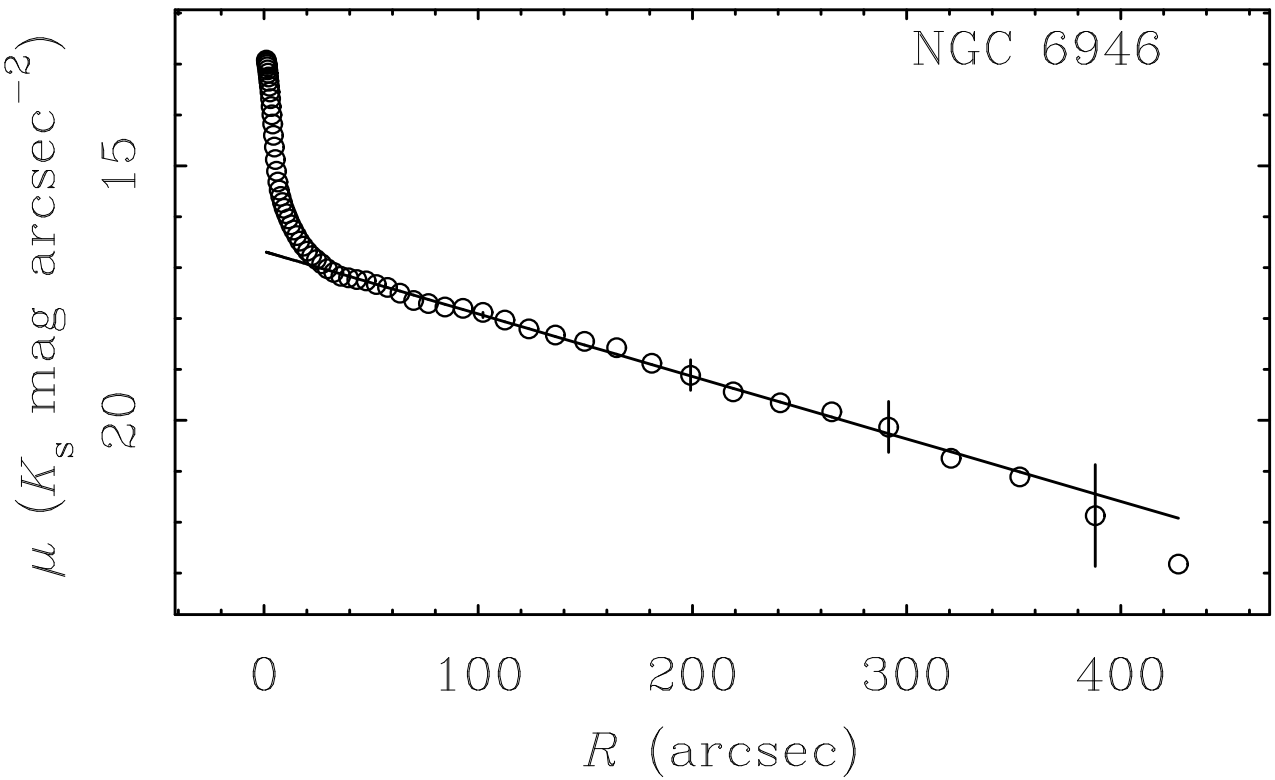
Rotation curves of late type disks (Sd, Sm, Irr)

Kuzio de Naray et al. (2006, 2008, 2009); Trachternach et al. (2009)

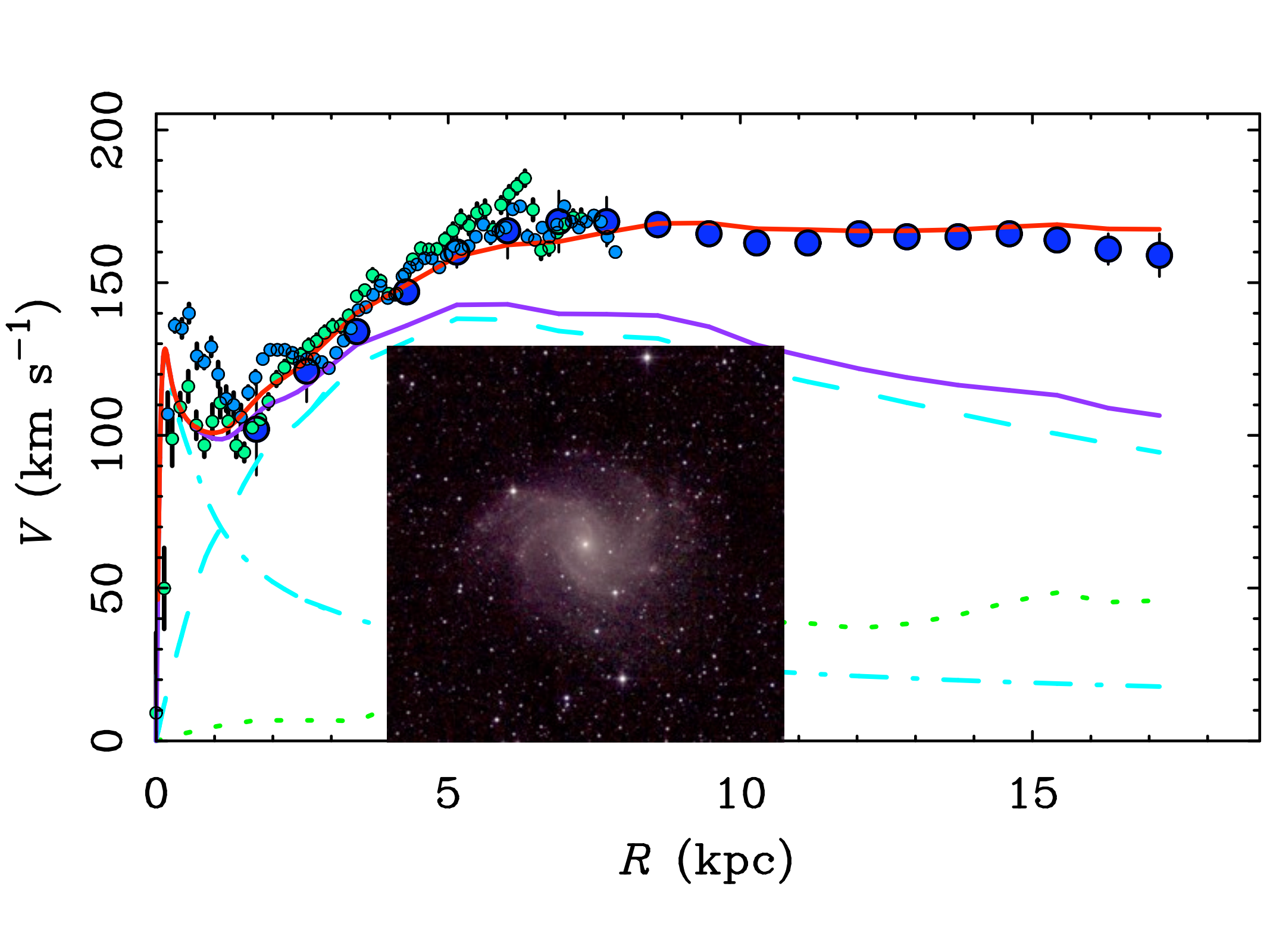
Light good predictor of inner RC - maximum disk



NGC 6946 has a small bulge (4% of the total light) that is only clear in the near-infrared.



the bulge does make a noticeable contribution to the mass model...


0
50
100
150
200
V (km s−1)
0
5
10
15
R (kpc)

Also illustrates "disk-halo conspiracy"

- V(halo) ~ V(disk)
- no clear transition between disk and halo