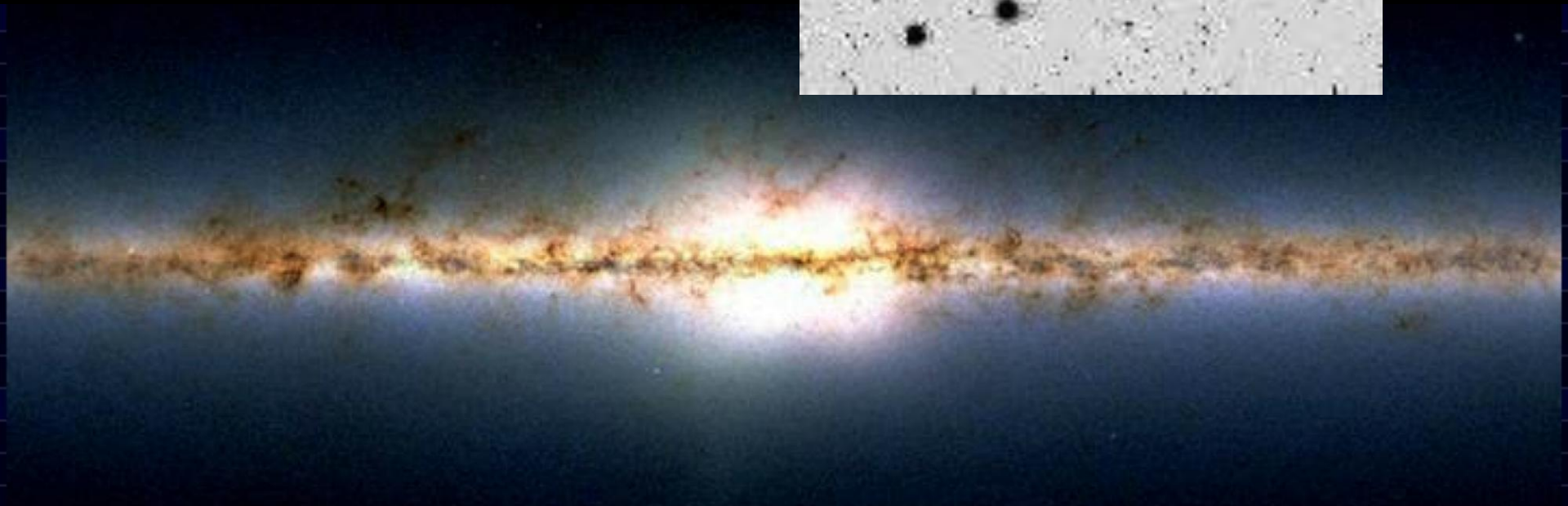
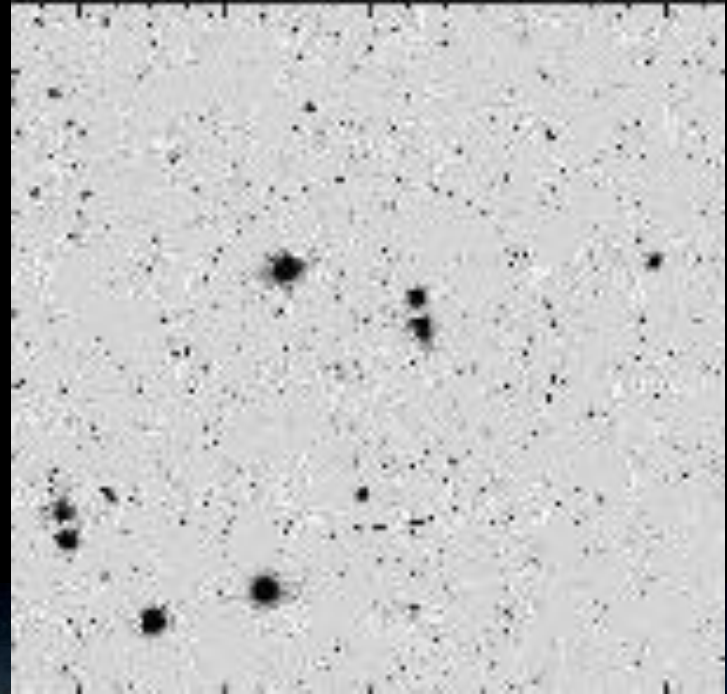
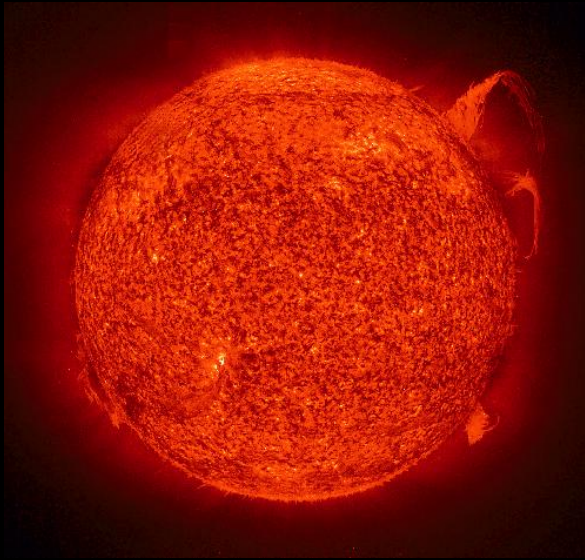


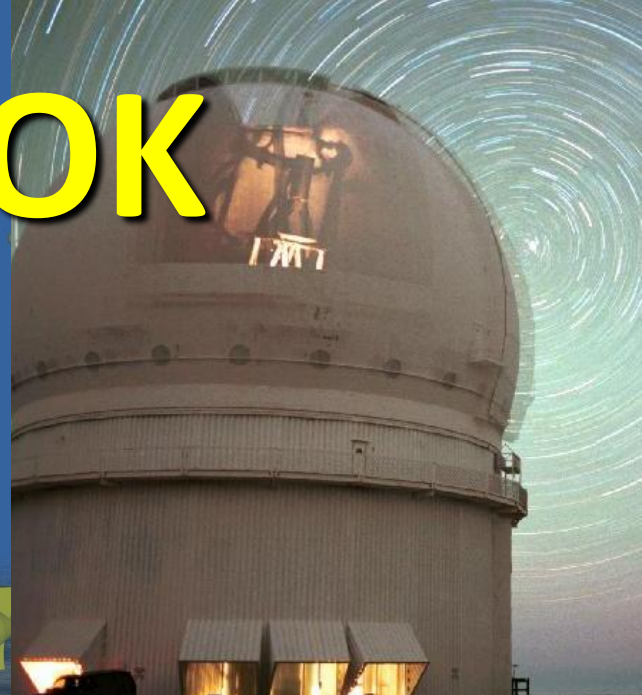
THE CHALLENGE OF DARK MATTER

**Joe Silk Oxford
July, 2010**

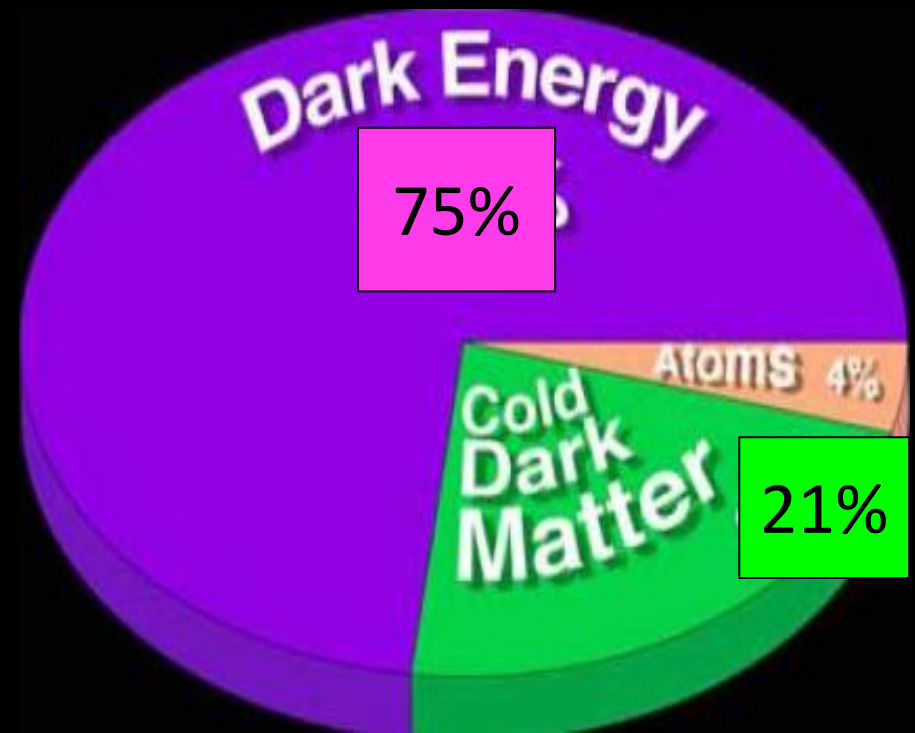
WHERE WE LOOK



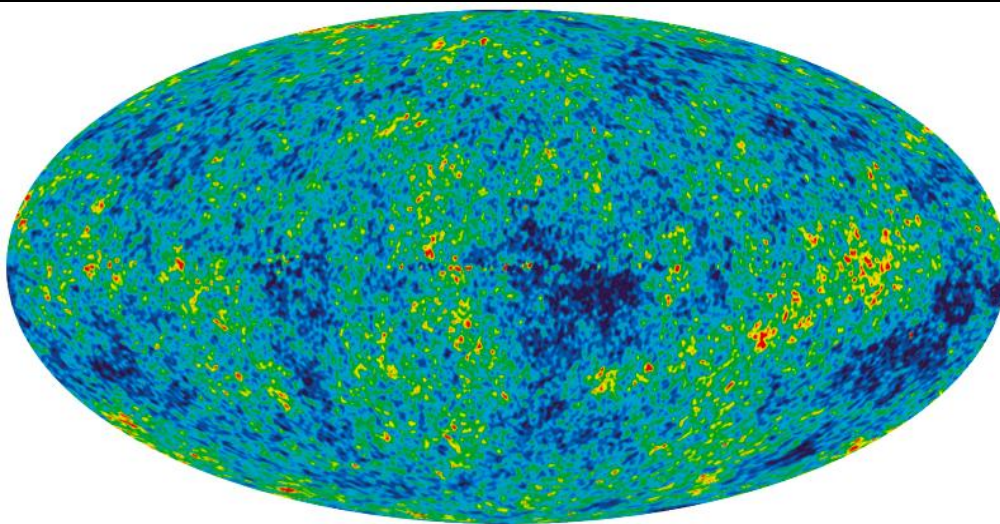
HOW WE LOOK



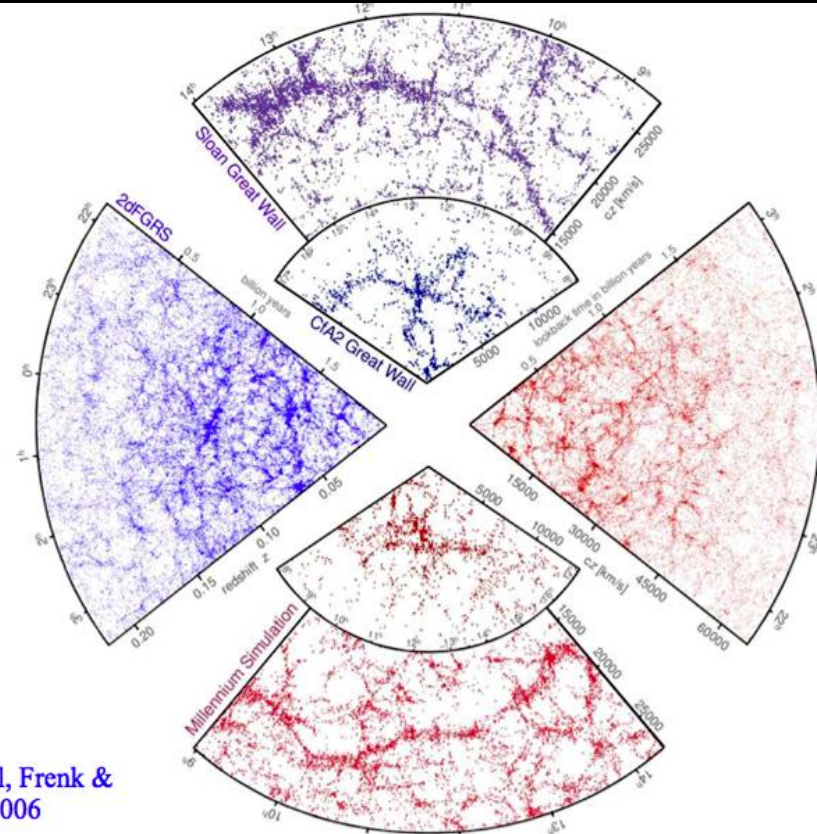
Constraints from cosmology



Dark Matter is weakly interacting & cold



-200 $T(\mu\text{K})$ +200 WMAP 5-year



Springel, Frenk & White 2006



Too many dwarf galaxies are predicted

A BRIEF HISTORY OF FEEDBACK

Add baryons to make realistic galaxies

But this creates more problems, e.g.

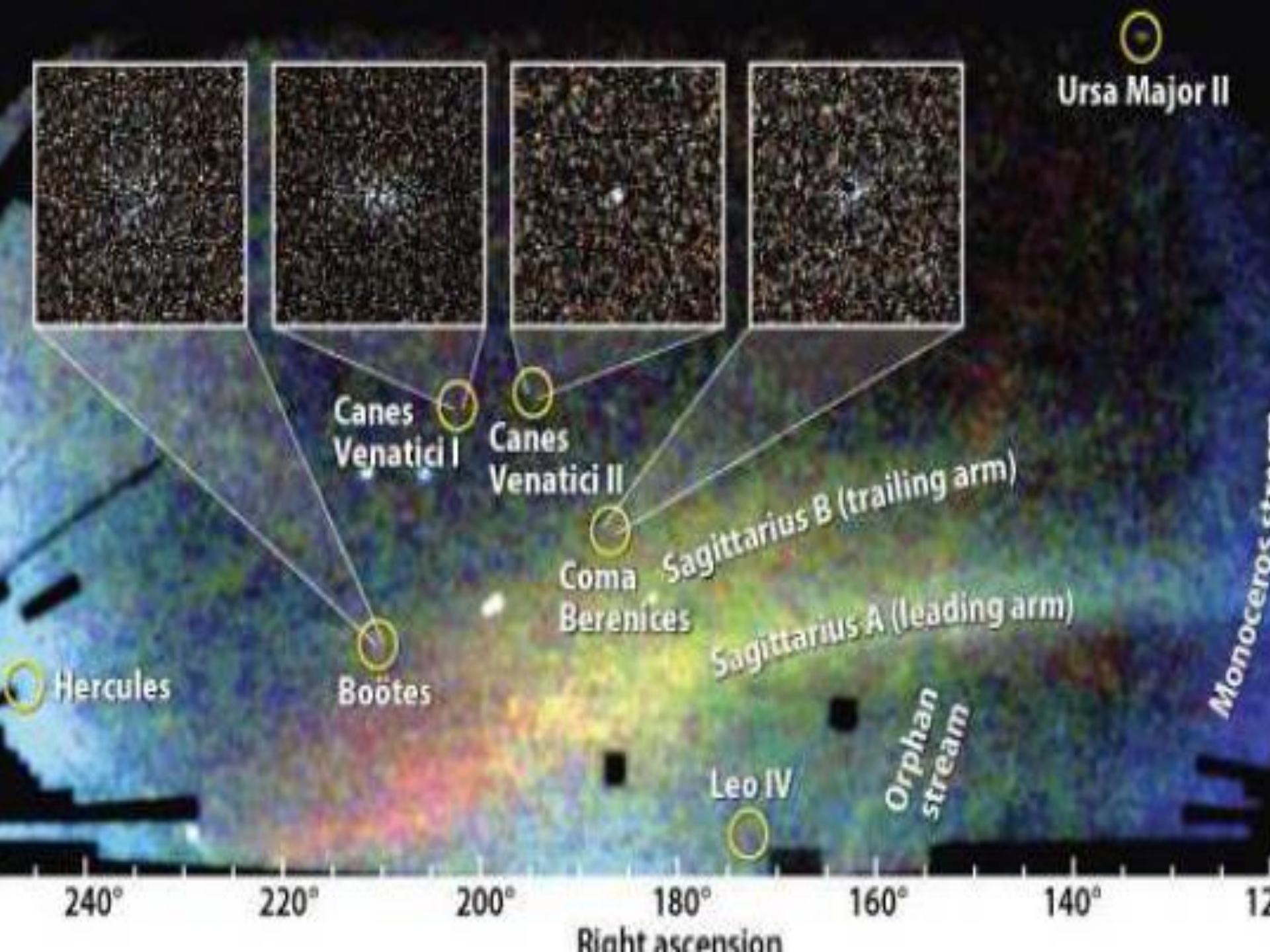
too many small galaxies
too many big galaxies...

Need to add astrophysical complexity, e.g.

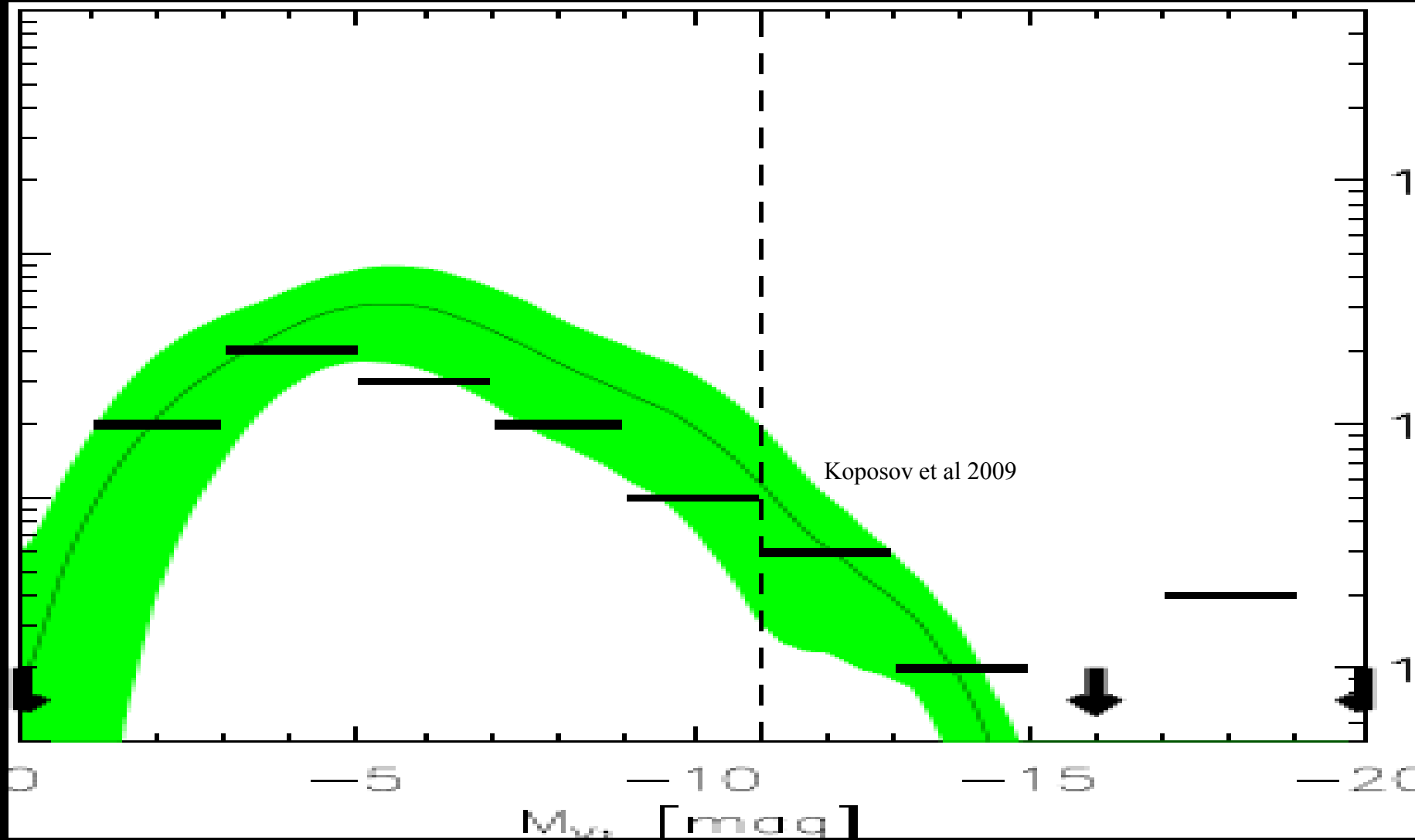
Reionization

Supernovae

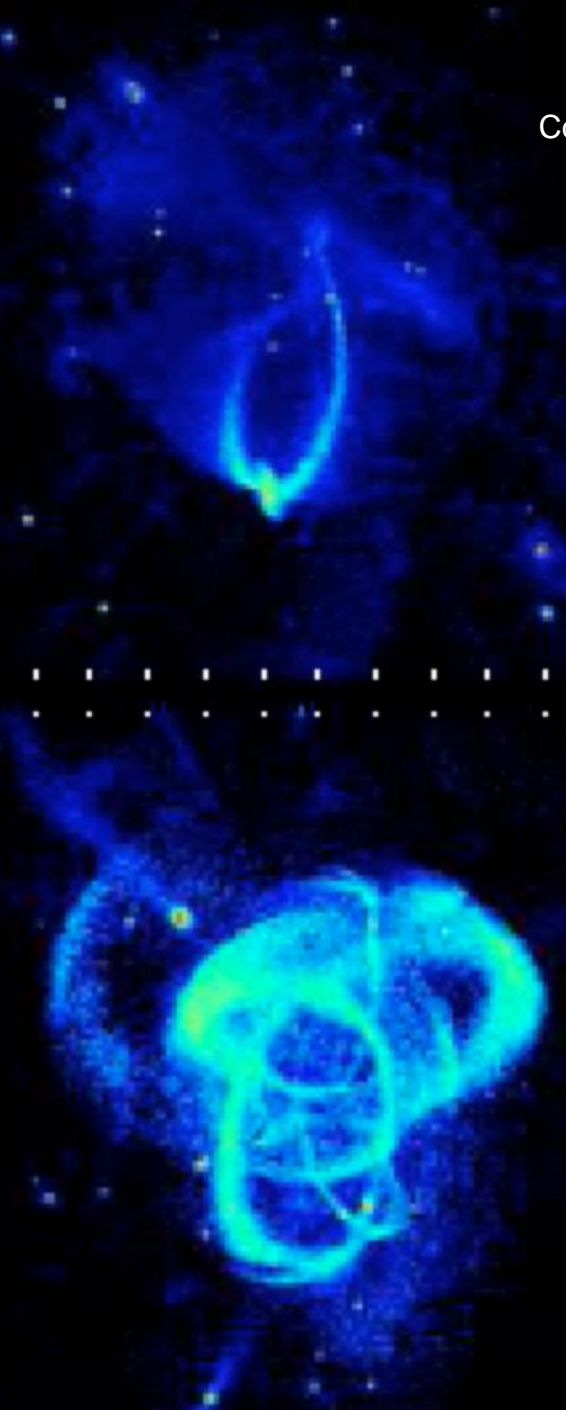
Supermassive black holes



Fitting the mass function of galaxies



Cooper et al 2010



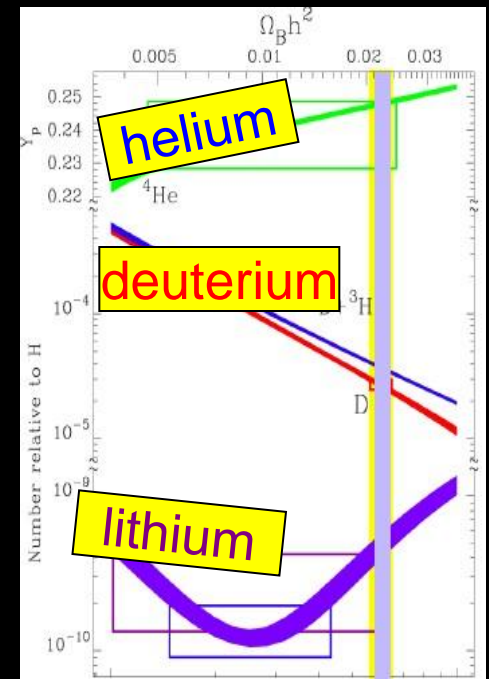
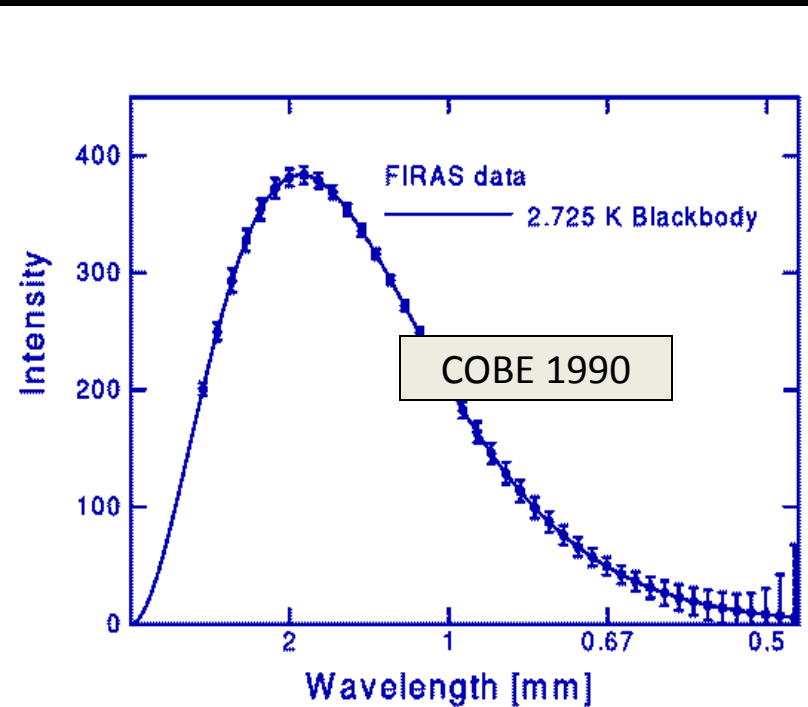
Martinez-Delgado et al 2008



**BUT WE CAN'T EXPLAIN
> 15% OF GALAXIES!**



Dark matter is not baryons

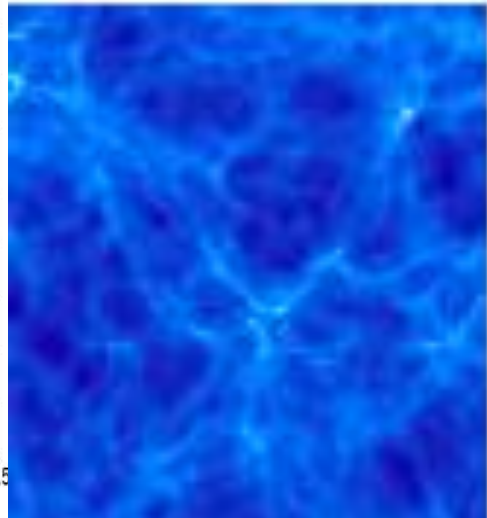
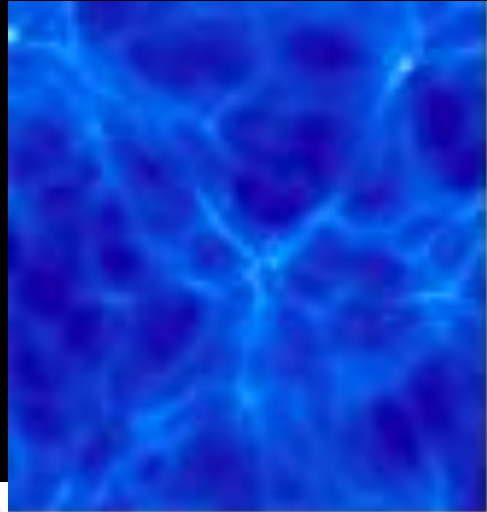
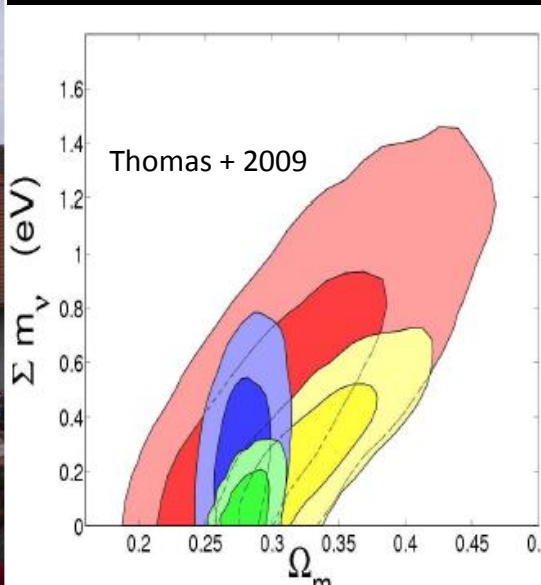


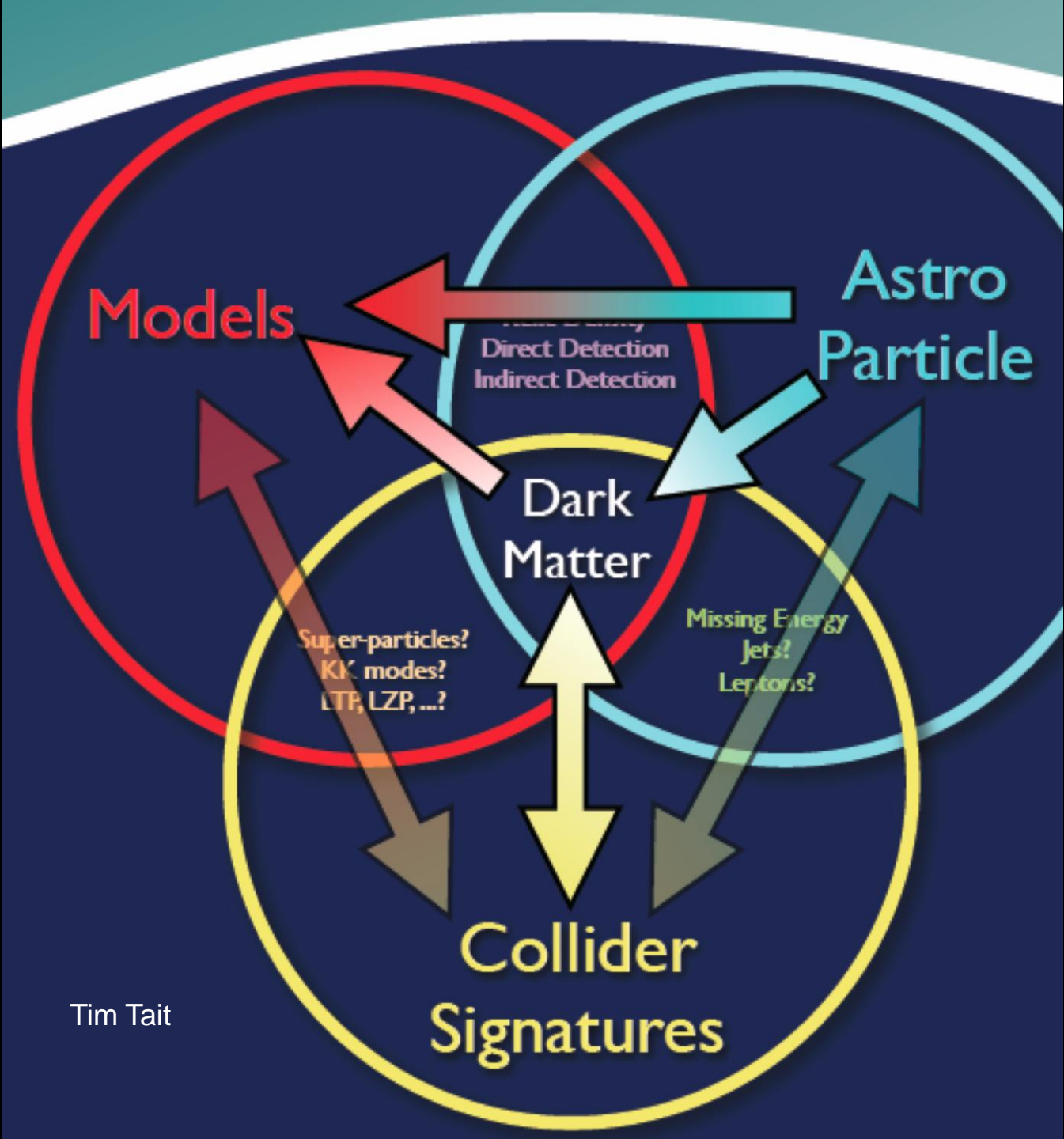
AS the cerebral discussions on the composition of the universe continue among the world's academics,

Professor J. Silk, from the Departments of Astronomy and Physics at the University of California arrives at the ANU to deliver a recitation on Baryonic Dark Matter, summarised in an advance notice thus: "At least 90 per cent of the mass of the universe is in the form of non-luminous matter."

Rumours that a class defamation action is pending are as yet unsubstan-

Dark matter is not neutrinos





Tim Tait

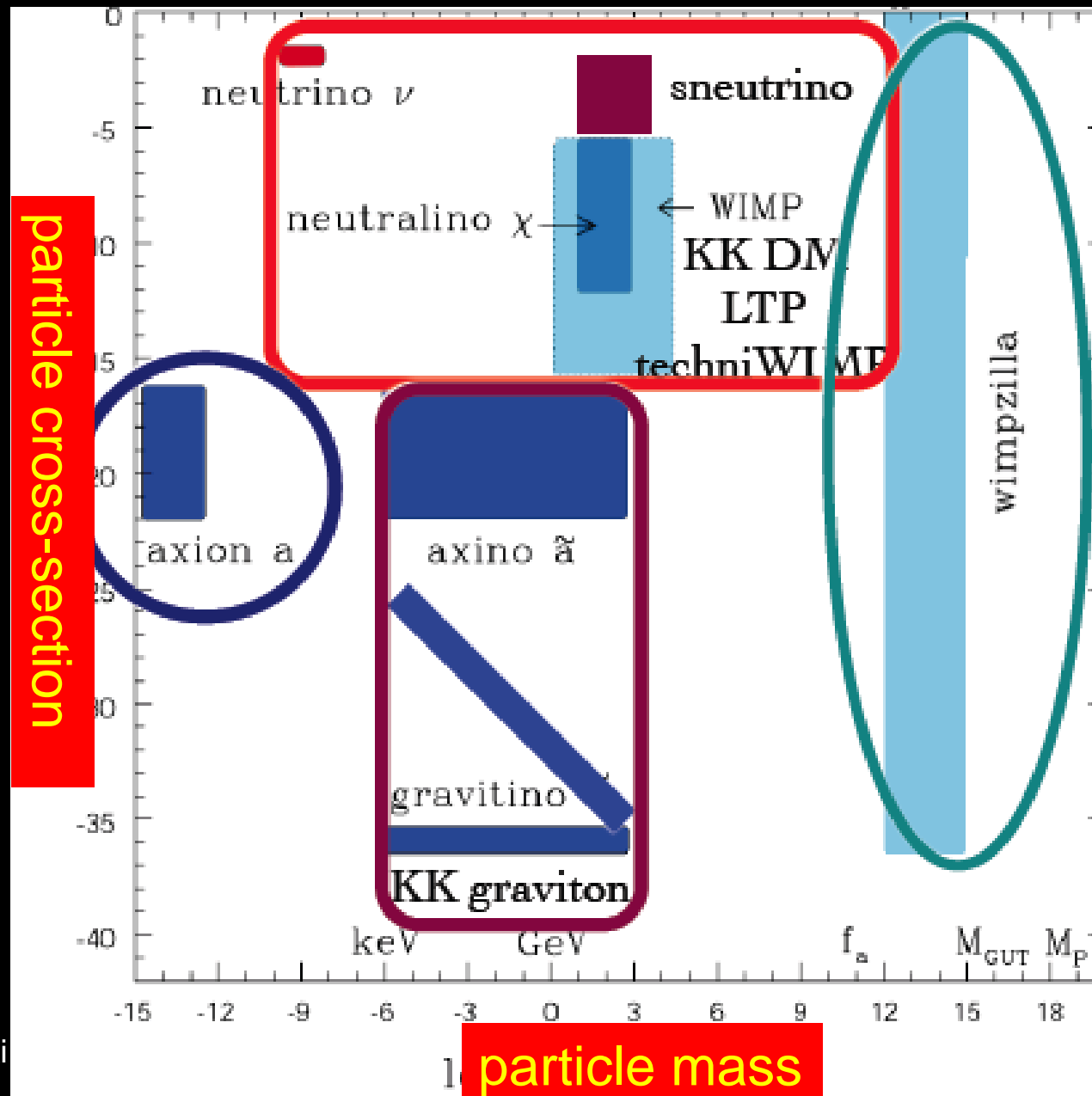
Dark matter most likely is
a weakly interacting (massive?) particle
aka WIMP or LSP
motivated by theory of supersymmetry

Favoured SUSY candidate is a WIMP in mass range 0.1-10 TeV

The WIMP miracle: relic abundance if $\langle\sigma v\rangle\sim 3\times 10^{-26}\text{ cm}^3/\text{s}\sim 1/\Omega_x$

Astrophysical probes of dark matter
complement collider experiments

The hunt is on for WIMPs and nonWIMPs



Direct detection: many WIMPs
pass through us every second

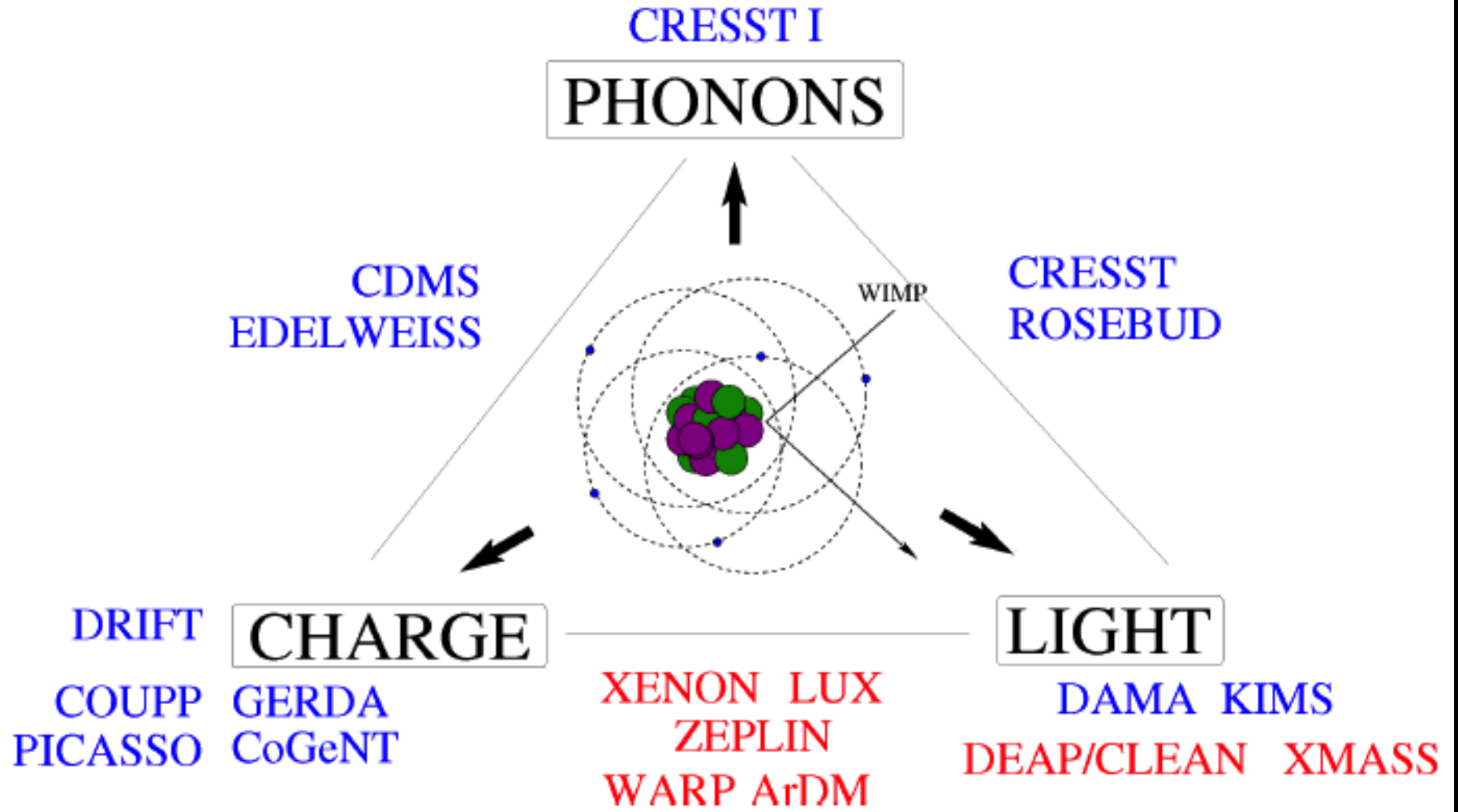
about ten million WIMPS per sq meter per sec pass through the earth

Indirect detection: halo WIMPS
occasionally annihilate today

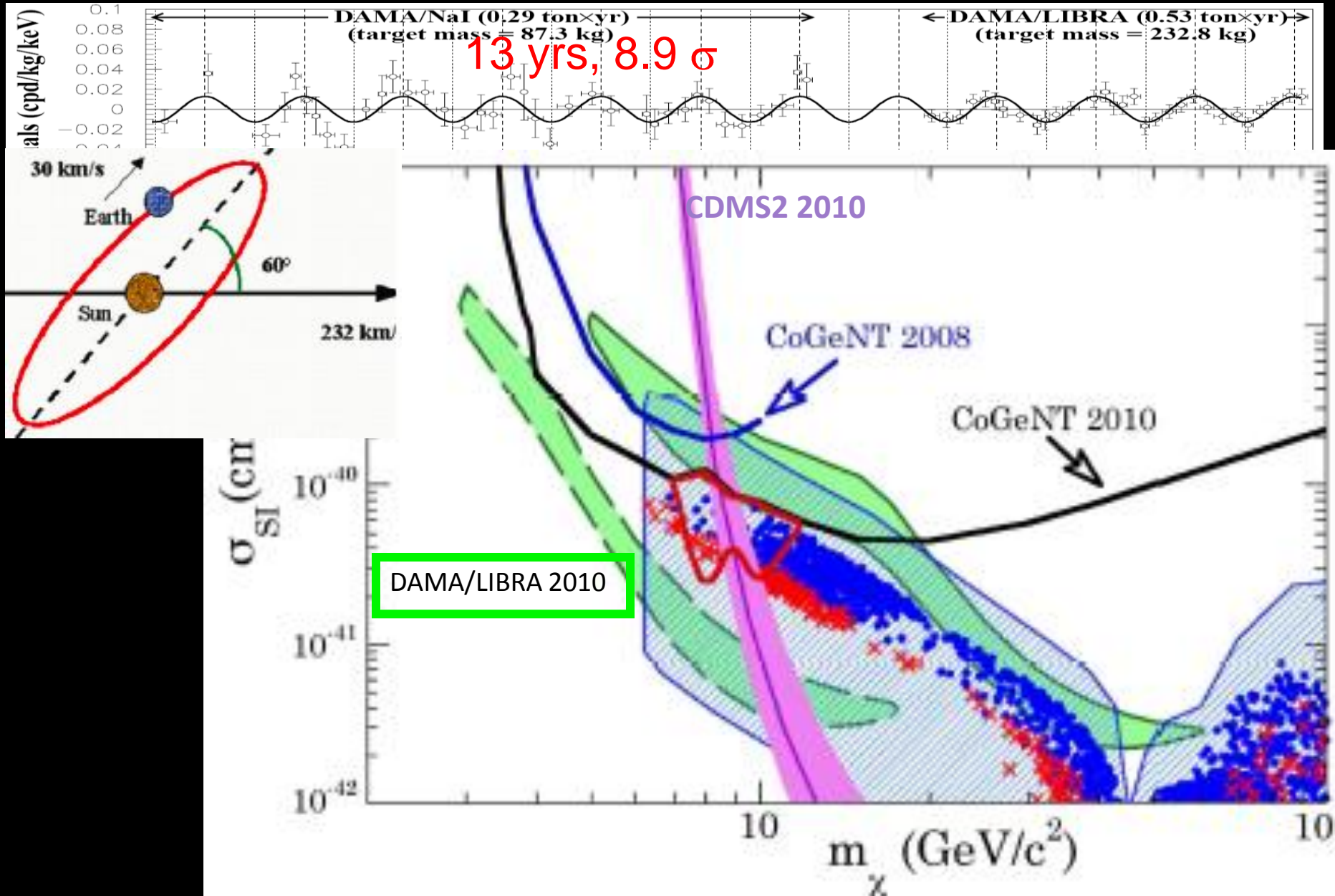
into energetic particles: $\nu, \gamma, \bar{p}, e^+$

Direct detection experiments

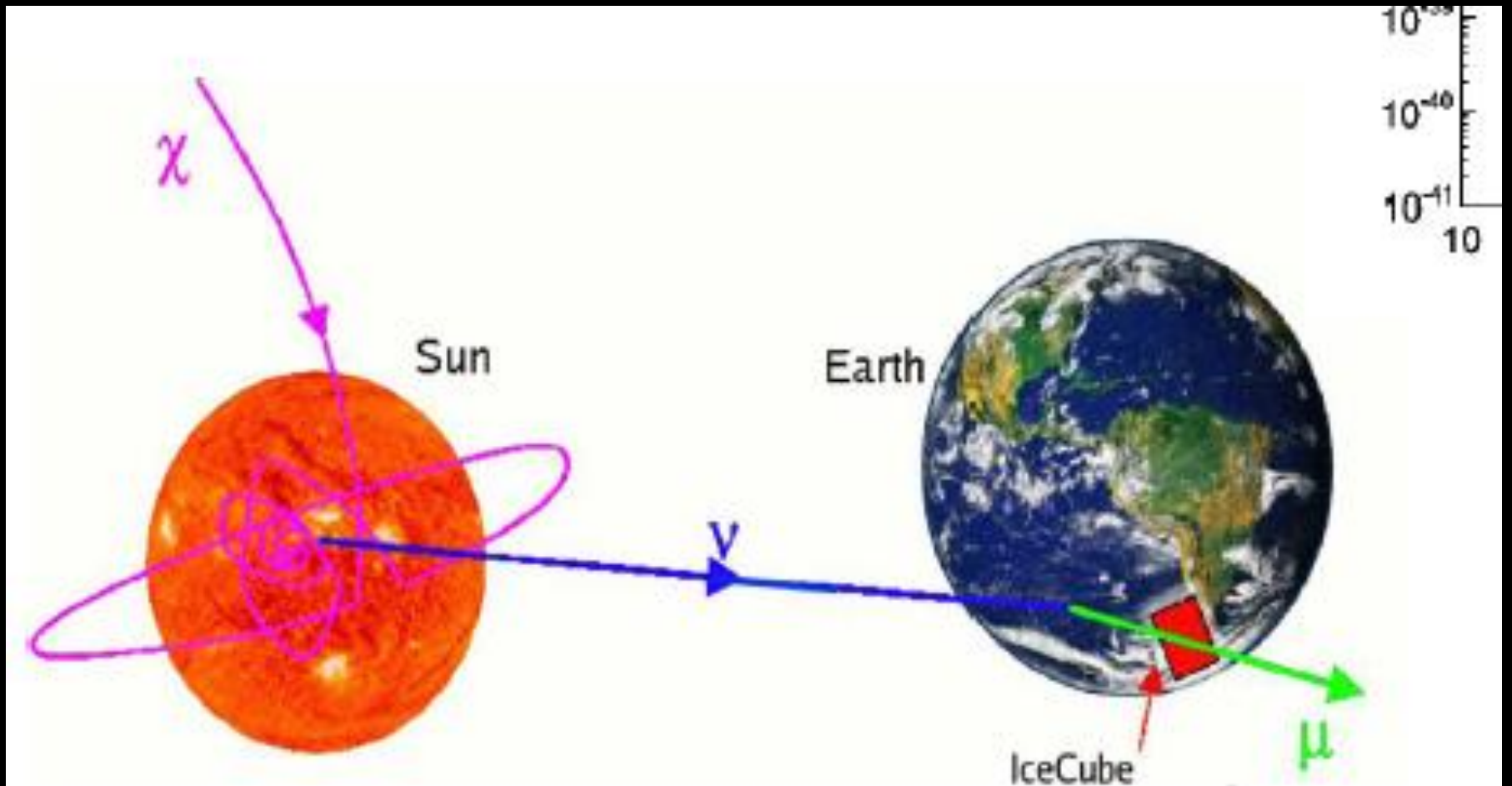
Teresa Marrodan



A controversial detection using solar modulation to enhance the direct detection signal

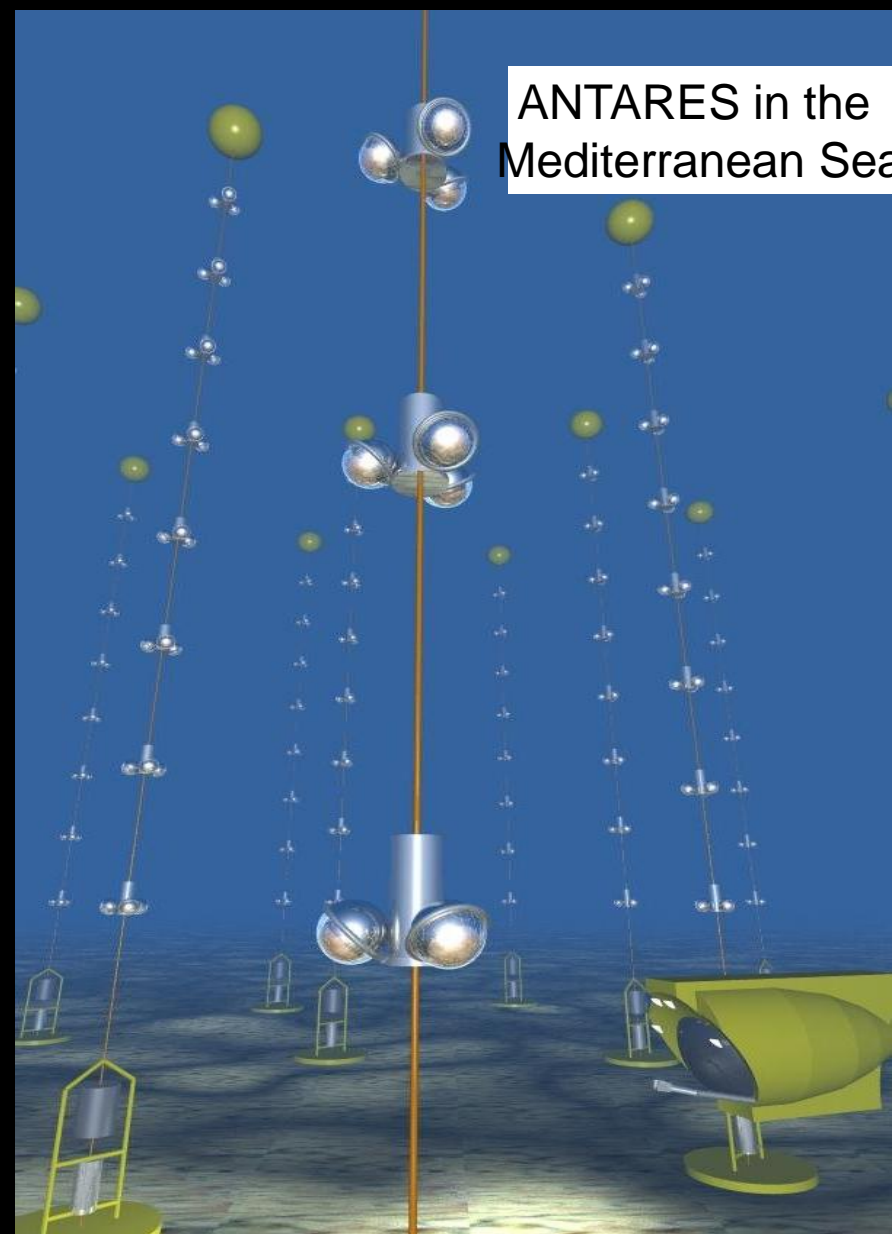
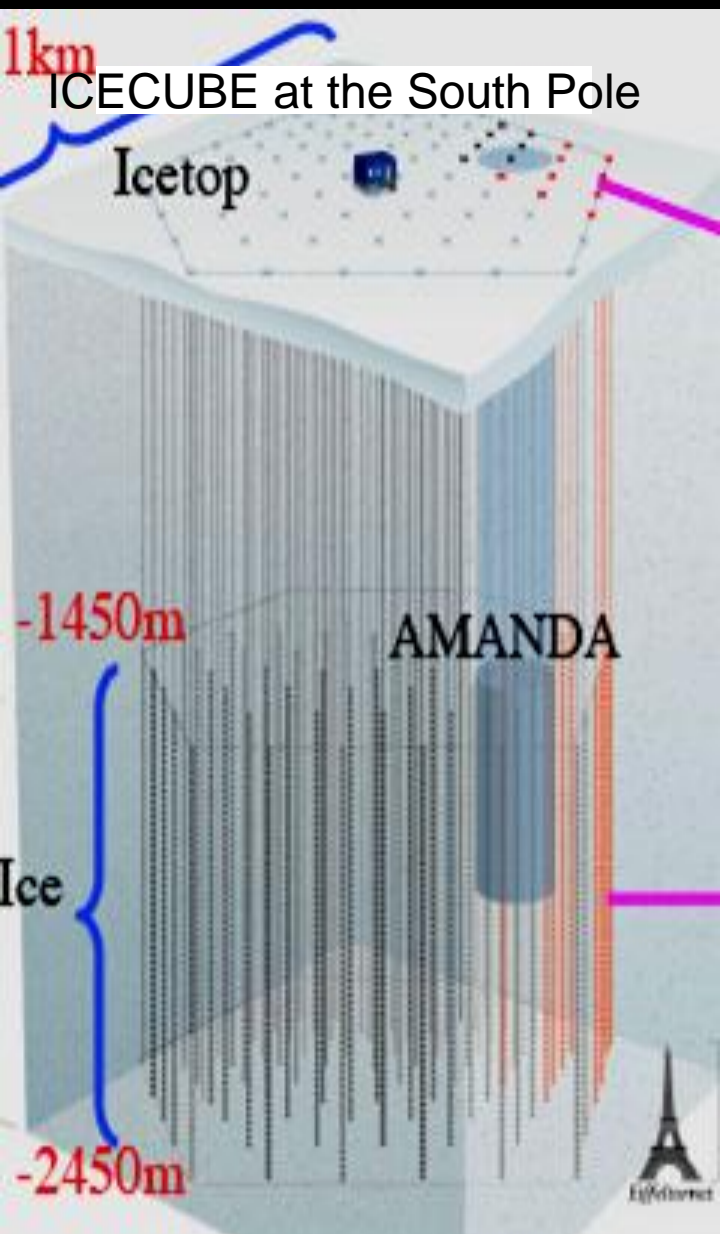


Indirect detection by using the sun as a dark matter trap



indirect detection: neutrinos

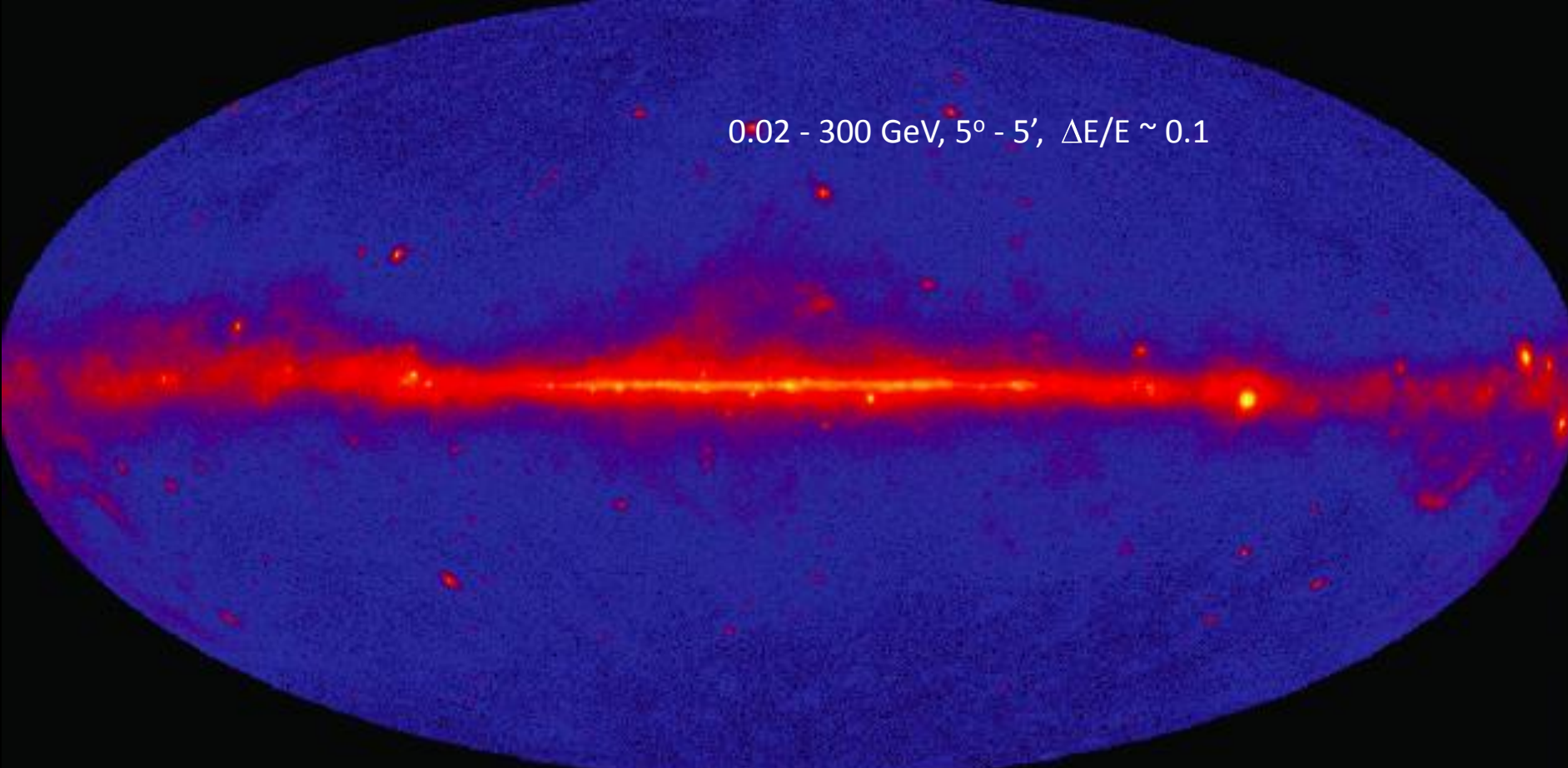
from WIMPs annihilating in the sun



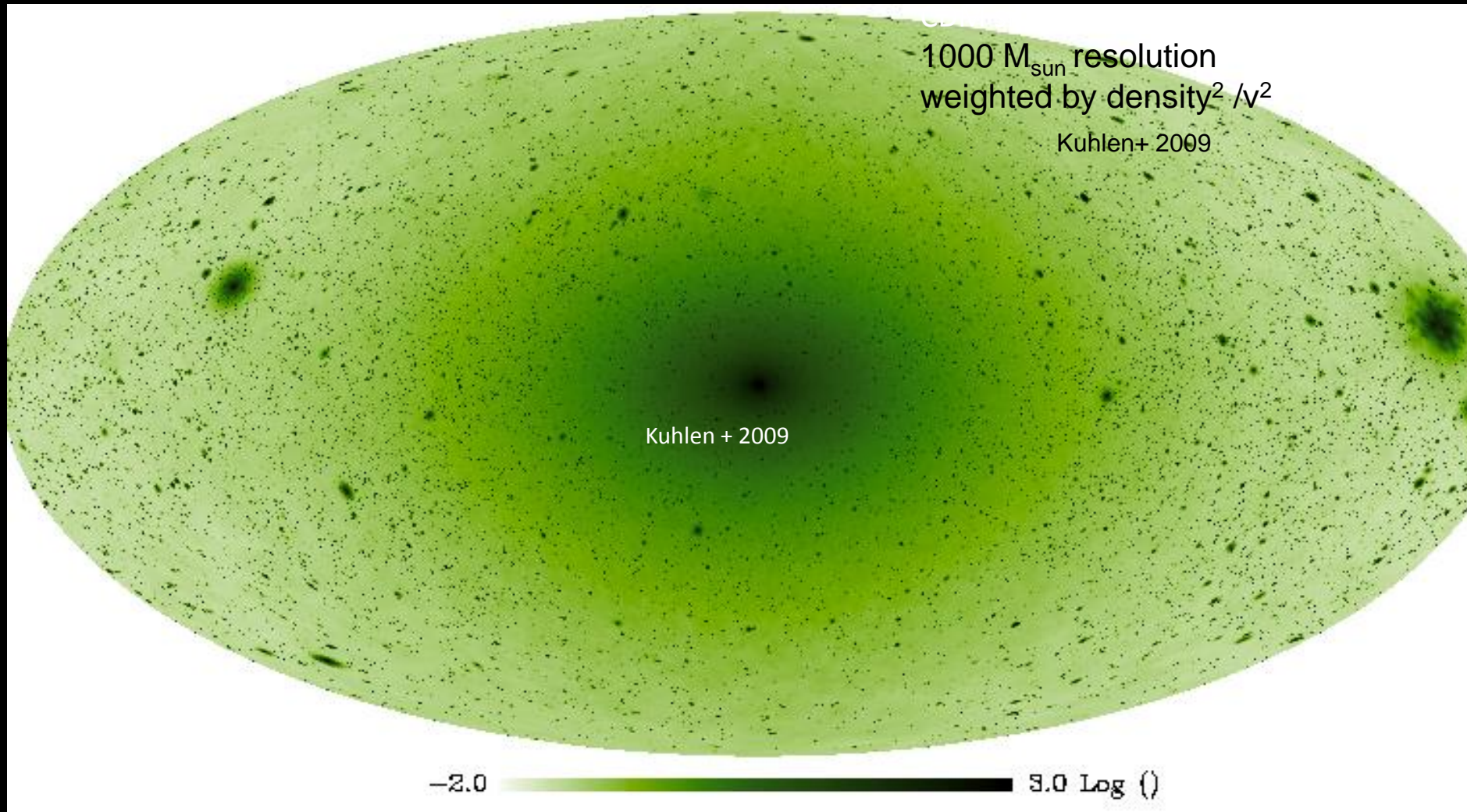
Indirect detection search by Fermi satellite: annihilation γ -rays from the Galactic centre

predict γ ray “smoking guns”: hard spectrum annihilation bumps/lines
Strongest signal is inverse Compton from annihilation high energy electrons/positrons

0.02 - 300 GeV, $5^\circ - 5'$, $\Delta E/E \sim 0.1$



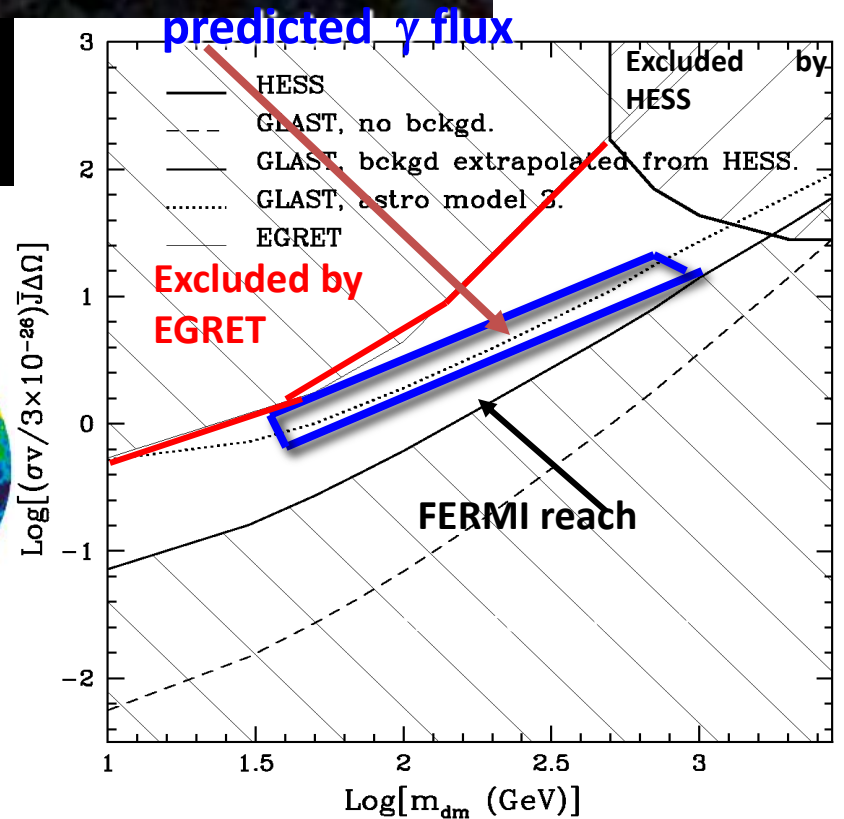
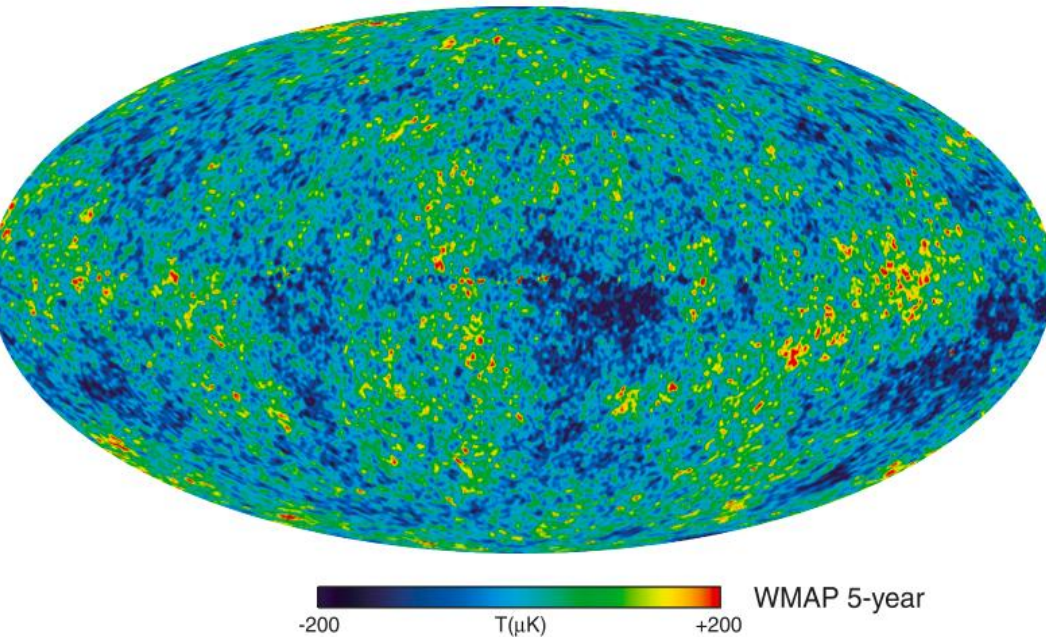
γ -rays from dwarf galaxies which are dark matter-dominated



So far only upper limits....

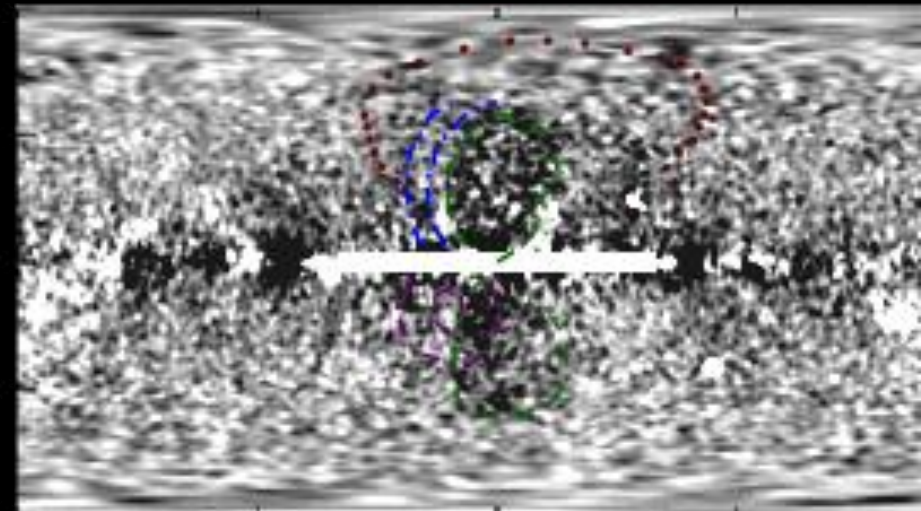
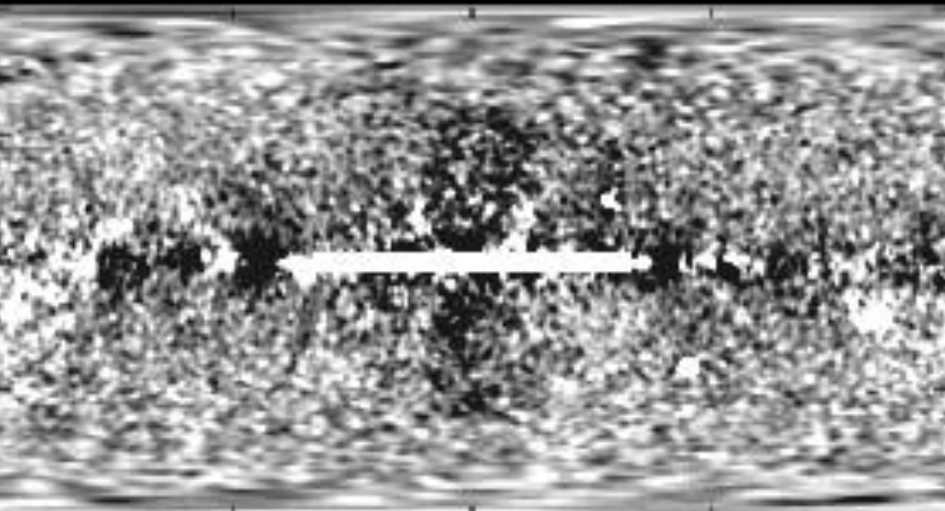
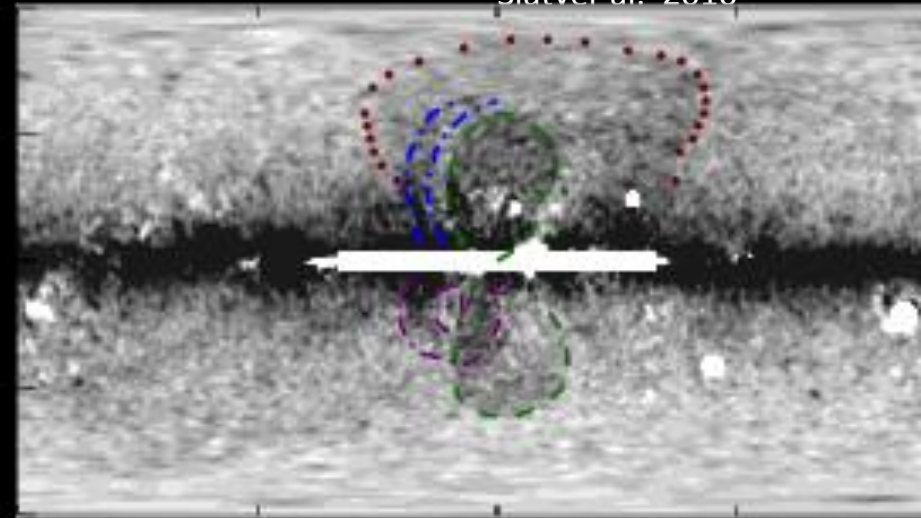
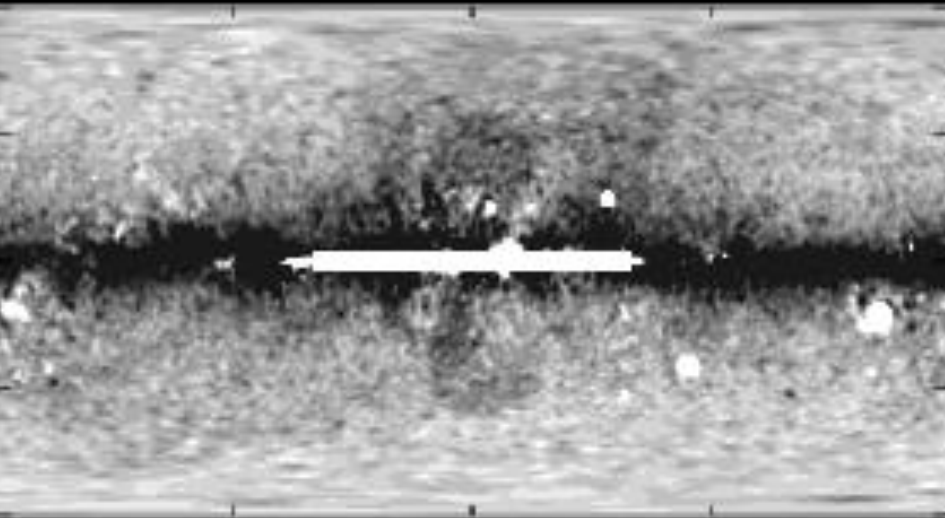
The WMAP microwave haze

Finkbeiner 2007

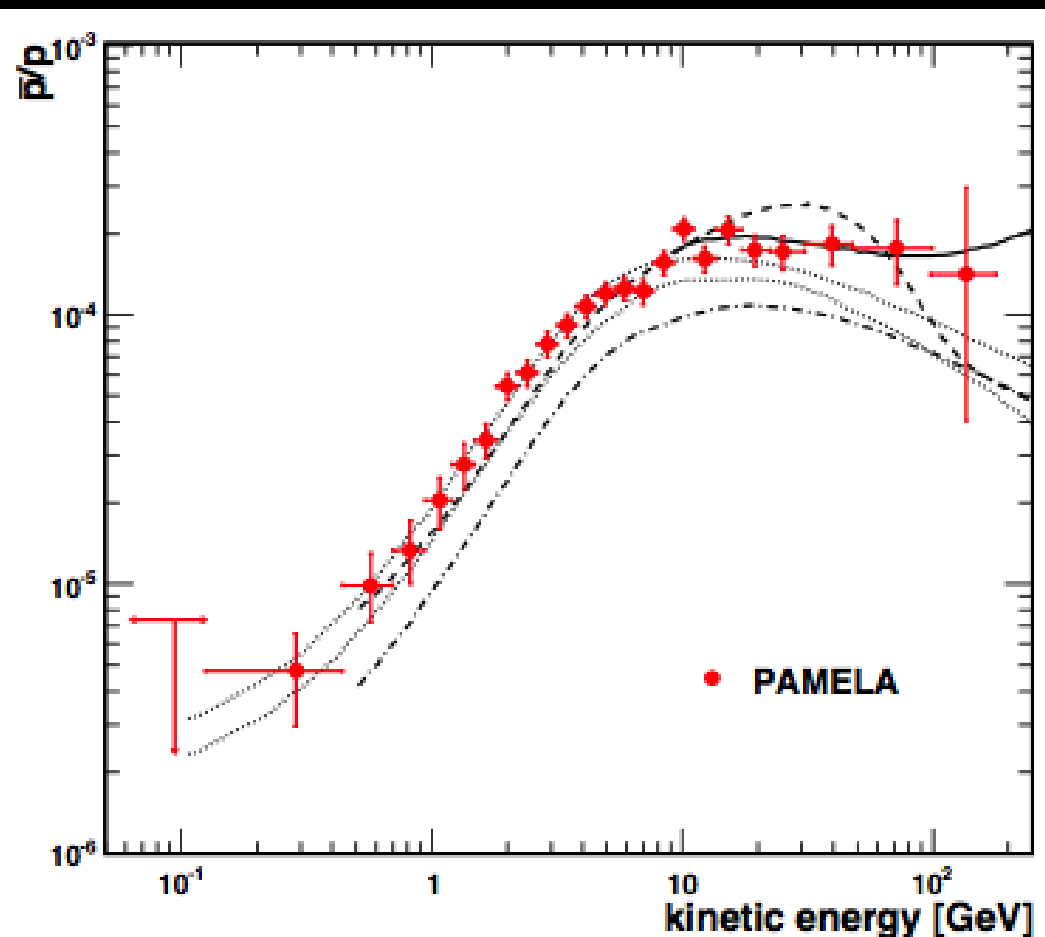


Fermi haze is inverse Compton of e^+e^- on interstellar radiation... but it doesn't look like a dark matter source is needed!

Slatver et al. 2010

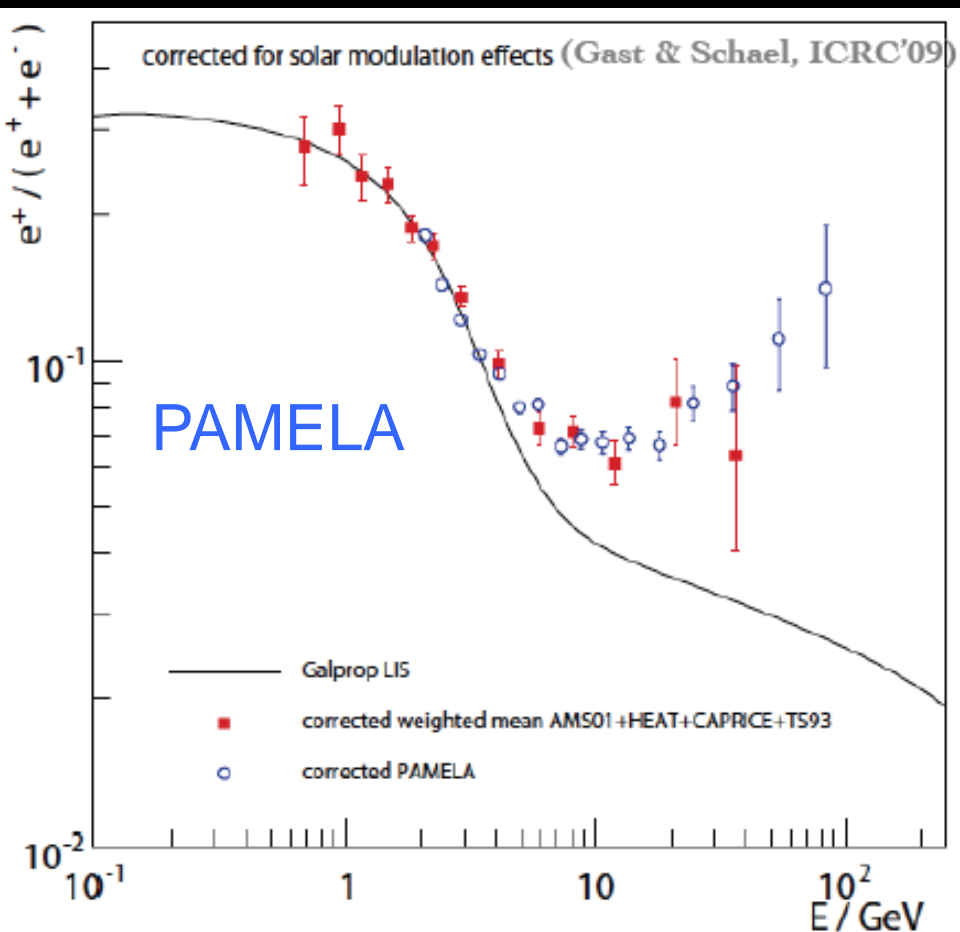


Indirect detection search for antimatter: antiprotons



No surprises so far!

Indirect detection search for antimatter: positron fraction



Adriani *et al*, Nature 458:607,2009

Could be a dark matter signature, but the rise plausibly has an astrophysical origin

DARK MATTER CHALLENGES COSMOLOGY

RESURRECTION VIA FUNDAMENTAL PHYSICS

- MODIFYING THE NATURE OF DARK MATTER?
- MODIFYING GRAVITY?

RESURRECTION VIA ASTROPHYSICS

- FEEDBACK

DARK MATTER DETECTION IS ESSENTIAL FOR CREDIBILITY

ONLY INDIRECT DETECTION IN MULTIPLE WINDOWS WILL
DEMONSTRATE ITS COSMOLOGICAL SIGNIFICANCE

extraordinary claims require extraordinary evidence.
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