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
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
Springel and Hernquist 2003

Orbital velocity $v_{esc} > 43$ km/s

Distance from centre of galaxy

Supernova-driven wind

Taylor 2006

Koposov et al. 2009

Milky Way satellites
Fitting the mass function of galaxies

Koposov et al. 2009
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 university is in the form of non-luminous matter."

Rumours that a class defamation action is pending are as yet unsubstantiated.
Dark matter is not neutrinos

Thomas + 2009
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 $\langle \sigma v \rangle \sim 3 \times 10^{-26}$ cm$^3$/s $\sim 1/\Omega_x$

Astrophysical probes of dark matter complement collider experiments.
The hunt is on for WIMPS and non-WIMPs

Leszek Roszkowski

particle mass

particle cross-section

wimpzilla

eutrino \nu
neutrino
neutralino \chi
WIMP
KK DM
LTP
techniWIMP
axion a
axino \tilde{a}
gravitino
KK graviton
keV
GeV
f_a
M_{GUT}
M_P
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

Diagram showing experimental setups for direct detection of dark matter, including PHONONS, CRESST I, CDMS, EDDELWEISS, CRESST ROSEBUD, DRIFT, COUPP, PICASSO, CHARGE, XENON, LUX, ZEPLIN, WARP, ARDM, DAMA, KIMS, DEAP/CLEAN, and XMASS.
A controversial detection using solar modulation to enhance the direct detection signal

13 yrs, 8.9 $\sigma$

DAMA/NaI (0.29 ton$\times$yr) (target mass = 87.3 kg)

DAMA/LIBRA (0.53 ton$\times$yr) (target mass = 232.8 kg)

CDMS2 2010

DAMA/LIBRA 2010

CoGeNT 2008

CoGeNT 2010
Indirect detection by using the sun as a dark matter trap
indirect detection: neutrinos from WIMPs annihilating in the sun

ICECUBE at the South Pole

ANTARES in the Mediterranean Sea
Indirect detection search by Fermi satellite: annihilation $\gamma$-rays from the Galactic centre

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

0.02 - 300 GeV, 5° - 5’, $\Delta E/E \sim 0.1$
\( \gamma \)-rays from dwarf galaxies which are dark matter-dominated

So far only upper limits....
The WMAP microwave haze

Excluded by HESS

FERMI reach

Finkbeiner 2007

predicted γ flux

Excluded by EGRET

WMAP 5-year

Log[\sigma v/(3 \times 10^{-26} \text{ cm}^3 \text{s}^{-1})] \Delta\Omega]

Log[\text{m}_{dm} \text{ (GeV)}]
Fermi haze is inverse Compton of $e^+e^-$ on interstellar radiation... but it doesn’t look like a dark matter source is needed!

Slatyer et al. 2010
Indirect detection search for antimatter: antiprotons

No surprises so far!
Indirect detection search for antimatter: positron fraction

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

PAMELA

Adriani et al., Nature 458:607, 2009
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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