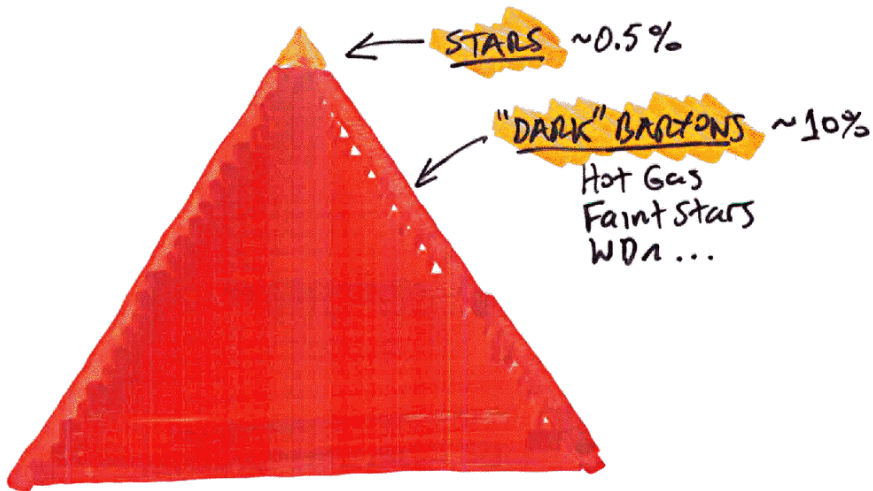


DARK SECTOR

CIRCA 1979

~~HYPERBOLIC~~, UNBOUND UNIVERSE

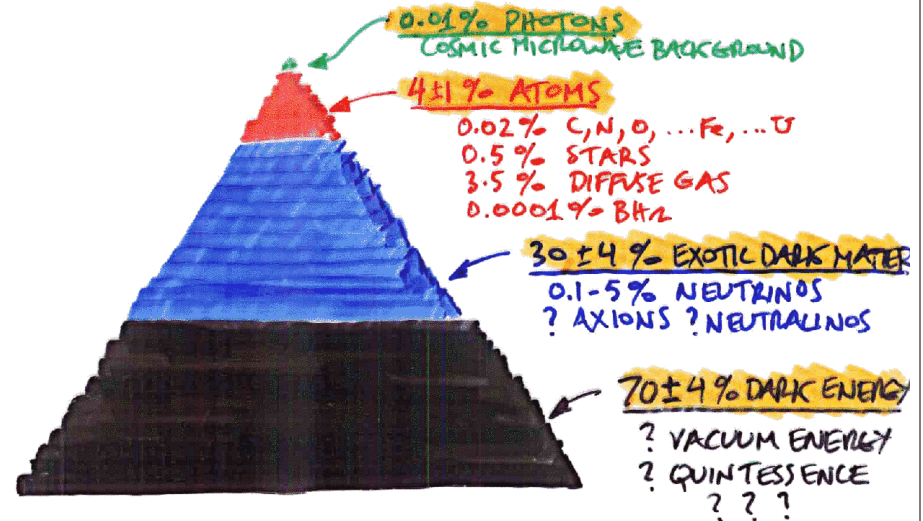
0.5% STARS + 10% DARK ATOMS
(RELATIVE TO CRITICAL DENSITY)



SIMPLE UNIVERSE

COSMIC STUFF

0.5% STARS + 30% DARK MATTER + 70% DARK ENERGY



96% IN NEW FORMS OF MATTER & ENERGY

COSMOLOGY CIRCA 1980

HIGH REDSHIFT $z_{950} \leq 3.5$ $z_{64} \leq 1$

CMB $T = 2.96 \pm 0.06$ 2.725 ± 0.001
 $\delta T_{DIPOL} \sim 3 \text{ mK}$
 $\delta T/T < 10^{-4}$ $\sim 10^{-5}$

LSS Shane-Wirtanen Catalogue 500K + REDSHIFTS

BBN $N_\nu < 4$

"CONCORDANCE MODEL"

$\Omega_\star \approx 0.005$
 $\Omega = \Omega_M = \Omega_B = 2g_0 \approx 0.01$
 $H_0 \sim 60 \text{ km s}^{-1} \text{ Mpc}^{-1}$
 "An Unbound Universe"



Age, BBN, Dynamic Measurements of Mass, g_0, H_0
 • Evidence for 3ν neutrinos

GROWING EVIDENCE FOR "DARK" MATTER

- Flat rotation curves V. Rubin et al
- Clusters Zwicky ...
- Hot x-ray emitting cluster gas accounts for DM?

DARK SECTOR 2004

INTERLOCKING WEB OF PRECISION MEASUREMENTS: BBN, CMB, LSS, Clusters, H_0 , SNe, ...

THE NUMBERS

BARYONS

$\Omega_B = 0.04 \pm 0.01$
 BBN, CMB
 $\Omega_\star \approx 0.005 - 0.01$
 (DAs count!)

NEUTRINOS

$\Omega_\nu = 0.001 - 0.05$
 ATM/SOLAR NEUTRINOS 2AF SDSS

MATTER TOTAL

$\Omega_M = 0.30 \pm 0.04$
 CLUSTERS/BBN; SDSS/WMAP

MATTER/ENERGY TOTAL

$\Omega_0 = 1.02 \pm 0.02$
 CMB/LSS

"DARK ENERGY"

$\Omega_x = 0.7 \pm 0.04$
 $w_x = -1 \pm 0.2$
 SNe Ia, CMB, CLUSTERS

$\equiv \langle P_x / \rho_x \rangle$

LESSONS

★ BE CAREFUL OF ASSUMPTIONS!

$$\Omega_0 = \Omega_M = \Omega_B$$

TODAY: $\Omega_0 = \frac{\langle \rho \rangle}{\rho_{crit}}$
 $= \sum_i \Omega_i$ $i = B, \nu, CDM, DE, ?$

★ SMALL PROBLEMS CAN BE IMPORTANT CLUES

WHAT WE KNOW

DARK MATTER

- ★ DOES NOT EMIT/ABSORB EM RADⁿ
- ★ WEAKLY INTERACTING
- ★ "COLD" SMALL INITIAL VEL. DISPERSION

DARK ENERGY

- ★ SMOOTH
- ★ VERY ELASTIC
- ★ WEAKLY COUPLED TO MATTER
- ★ LIKE EINSTEIN'S COSMO. CONST

OF MOOSE DIAGRAM DARK MATTER CANDIDATES

MT90



LEARNING ABOUT DARK ENERGY

★ CAN BE DESCRIBED BY

Pronounced "Duhya" $w \equiv P_x / \rho_x$

NB: w may vary with time

current data: $w = -1 \pm 0.2$

CANDIDATE	w	\dot{w}
VACUUM ENERGY	-1	0
TANGLED DEFECT	-1/3	0
ROLLING FIELD	-1 to 1	$\neq 0$
GHOSTLY FIELD	< -1	$\neq 0$
NEW GRAV PHYSICS	< 0, IMAG	$\neq 0, 0$

★ COSMIC EFFECTS

$$H(z)^2 = \Omega_M(1+z)^3 + \Omega_X(H_0)^2(1+z)^{3(1+w)}$$

DISTANCES
 $r(z) = \int_0^z dz/H(z)$

GROWTH OF STRUCTURE
 $\ddot{\delta} + 2H\dot{\delta} - 4\pi G\rho_M\delta = 0$

★ HEAVENLY MEASUREMENTS

$$\sigma_w \sim 0.05 \quad \sigma_{\dot{w}} \sim 0.1$$

... AND DON'T FORGET ACCELERATORS

DARK QUESTIONS

- ★ What are the dark baryons?
VERY INTERESTING ASTROPHYSICS
- ★ For that matter, where did the baryons come from?
BARIOGENESIS - ROLE OF NEUTRINOS
- ★ What is the dark matter?
HOW MUCH NEUTRINOS? WHAT IS THE CDM?
- ★ How much does nothing weigh?
ENUF SAID! #
- ★ What is dark energy?
IS THERE ANY!?
- ★ Who ordered that!?
WHY $\Omega_{CDM} \sim \Omega_B \sim \Omega_\nu \sim \Omega_{DE}$?
- ★ What is our cosmic destiny?
TIED TO UNDERSTANDING DARK ENERGY
- ★ New theory of gravity?
*GM HYPOTHESIS - YES?
DARK MATTER - PROBABLY NO
DARK ENERGY - ??*

DARK PROGRESS

- ★ THEORISTS HAVE LOTS OF WORK
"KNOW MUCH, UNDERSTAND LITTLE"
- ★ MORE CLUES
LHC, CMB/SZ, SNE, JDEM, DM DETECTION,
- ★ ROOM FOR SURPRISES!
*- NO AXION OR NEUTRALINO
- WARM DM
- FTM BREAKDOWN*