Liebscher 17.3.93

DARK MATTER VERSUS COSMOLOGICAL CONSTANT

DARK MATTER IN ASTROPHYSICS

- **Source of graviational field, but**
- **nor source nor transmitter of electromagnetic radiation**

DARK PARTICLES

- **Energy-momentum conservation**
- **Conservation of charges**
- **Symmetry partners**
- **Topological peculiarities**
- **Virtual particles: Vacuum**

COSMOLOGICAL CONSTANT

- **Curvature-matter balance**
- **Zero-point curvature: No phase transitions**
- **Vacuum: Phase transitions**

THE FRIEDMANN EQUATION

SPACE-TIME CURVATURE = MASS DENSITY

EXPANSION RATE	+	SPACE CURVATURE	=	VIRTUAL MASS DENSITY	+	REAL MASS DENSITY
$\left(\frac{1}{R}\frac{\mathrm{d}R}{\mathrm{d}t}\right)^2$	$+$	$\frac{kc^2}{R^2}$	$=$	$\frac{\Lambda c^2}{3}$	$+$	$\frac{8\pi G}{3}\varrho$
$h^2[z]$	$+$	$\kappa_0(1+z)^2$	$=$	λ_0	$+$	$\sum_n \Omega_{n0}(1+z)^n$
1	$+$	κ_0	$=$	λ_0	$+$	$\sum_n \Omega_{n0}$

Balancing the expansion rate by

- **radiation :** $n = 4$
- **dust (free streeming dark matter or interacting dust with negligible pressure):** $n = 3$
- **gas of strings:** $n = 2$ **(like curvature)**
- **gas of domain walls:** $n = 1$
- **vacuum:** $n = 0$ **(like cosmological constant)**

Kardashov,N.S. 1990

LACK OF GRAVITATING MASS

- **General reviews**

  Peebles,P.J.E., Schramm,D.N., Turner,E.L., Kron,R.G. 1991

  Schramm,D.N. 1992

- **Rotation curves of Galaxies**

  Ashman,Keith M. 1992

  Brainerd,T.G., Villumsen,J.V. 1992

  Brainerd,T.G., Villumsen,J.V. 1992

- **Galaxy formation**

  Dekel,A., Silk,J. 1986

- **Velocity dispersion in groups of galaxies**

  Ninkovich,S., Chernin,A., Shakenov,M. 1990

- **Polar rings in hypergalaxies**

  Einasto,Jaan, Haud,Urmas, Joeveer,Mihkel, Kaasik,Ants 1976

  Sackett,P.D., Sparke,L.S. 1990

- **Velocity dispersion of clusters of galaxies**

  Kauffmann,G., White,S.D.M. 1992

- **Growth of primordial post-recombination perturbations (Time problem of primeval structure formation)**

  Davis,M., Summers,F.J., Schlegel,D. 1992

- **Extra power on large scales**

  Davis,M., Efstathiou,G., Frenk,C.S., White,S.D.M. 1992

- **Friedmann balance of cosmic expansion**

  Guth,Alan H. 1981

MASS DENSITIES

Reduced masses	$\frac{M}{L}$ $\left[\frac{M_\odot}{L_\odot}\right]$	ϱ $\left[\frac{M_\odot}{\mathrm{Mpc}^3}\right]$	$\Omega = \frac{\varrho}{\varrho_{\mathrm{crit}}}$
Microwave background		$\mathbf{7\ 10^{-3}}$	$\mathbf{2.5\ 10^{-5}}h^{-2}$
Luminous matter	**5** h	**0.65** h^2	$\mathbf{2.4\ 10^{-3}}$
Galaxy halos	**10** h	**1.11** h^2	$\mathbf{4.7\ 10^{-3}}$
Hypergalaxy halo	**25** h	**2.77** h^2	**0.01**
Baryonic matter		**2.95**	**0.011** h^{-2}
Cluster halo	**325** h	**36** h^2	**0.13**
Critical density		**273** h^2	**1**

DARK MATTER TYPES

- **Review**
  Gelmini,G.B. 1992
- **Ordinary particles SU(3)×SU(2)×U(1)**
  Persic,Massimo, Salucci,Paolo 1992
  - **Dark baryons (brown dwarfs, gas, stillborn galaxies)**
  - **Massive Neutrinos**
  - **WIMPs (100 GeV)**
- **Particles beyond SU(3)×SU(2)×U(1)**
  - **Supersymmetric partners**
    Domenech,G., Levinas,M., Umerez,N. 1991
    Berezinsky,V.S., Gurevich,A.V., Zybin,K.P. 1992 **:**
    - **Gravitinos**
      Frieman,J.A., Giudice,G.F. 1989
    - **Neutralinos**
      Gelmini,G.B. 1992
  - **Shadow matter**
    Kolb,E.W., Seckel,D., Turner,M.S. 1985
    Sciama,D.W. 1990
  - **Cryptons**
    Ellis,J., Lopez,J.L., Nanopoulos,D.V. 1990
  - **Mirror baryons**
    Hodges,H.M. 1993
  - **Massive BH**
    Hut,P., Rees,M.J. 1992
  - **Maximons**
    Markov,M.A. 1993
- **Topological particles:**
  - **Strings**
    Arnowitt,R., et al. (eds.) 1990
  - **Axions (10^{-5} eV)**
    Turner,M.S. 1990
  - **Textures**
    Silk,J., Juszkiewicz,R. 1991

DIRECT AND INDIRECT OBSERVATIONS

- **Particle detection (underground physics)**

  Caldwell,D.O. 1992

- **Limits on particles by observation of the galactic halo**

  Berezinsky,V.S., Gurevich,A.V., Zybin,K.P. 1992

- **Long-range interaction**

  Stubbs,C.W. 1993

- **Influence on big bang nucleosynthesis**

  Hagelin,J.S., Parker,R.J.D. 1990

- **Influence on chemical evolution**

  Matteucci,F. 1992

- **Influence on density fluctuations**

  Taylor,A.N., Rowan-Robinson,M. 1992

- **Influence on structure formation**

  Vandalen,A., Schaefer,R.K. 1992

  Davis,M., Summers,F.J., Schlegel,D. 1992

ALTERNATIVES

- **Magnetic fields instead of dark matter**

  Binney,James 1992

  Fahr,H.J. 1990

- **Cosmological constant**

  Gessner,E. 1992

- **Non-Newtonian forces**

  Dar,A. 1992

  Gerhard,O.E., Spergel,D.N. 1992

  Gradwohl,B.A., Frieman,J.A. 1992

- **low density**

  Bahcall,Neta A., Cen,Renyue 1992

  Davis,M., Efstathiou,G., Frenk,C.S., White,S.D.M. 1992

  Liebscher,D.-E., Priester,W., Hoell,J. 1992

  Liebscher,D.-E., Priester,W., Hoell,J. 1992

COSMOLOGICAL CONSTANT AND VACUUM ENERGY

- **Constant: Geometrical quantity, measurement only by geometry**
  To first order in redshift: deceleration parameter

$$q = \frac{1}{2}\frac{\mathrm{d}h[z]}{\mathrm{d}z} - 1 \tag{1}$$

- **Vacuum: subject to phase transitions**

VACUUM PHASE TRANSITIONS

- **Inflation**
  Guth,Alan H. 1981
- **Late-type cosmological phase transitions, no more exotic than GUT**
  Schramm,D. 1991
- **Effective (classical) vacua (for instance S.Antoci)**
- **Kaluza-Klein phase transitions**
  Bengtson,Ingemar, Boström,Olaf 1992

COSMOLOGICAL CONSTANT

- **Review**
  Carroll,S.M., Press,W.H., Turner,E.L. 1992
  Peebles,P.J.E., Schramm,D.N., Turner,E.L., Kron,R.G. 1991
- **Zero cosmological constant**
  Carlberg,R.G. 1991 **Merging of galaxies $\propto (1+z)^5$**
  Kochanek,C.S. 1992 **Gravitational lensing**
  Kellermann,K.I. 1993 **Size of ejecta of radio galaxies**
- **Nonzero cosmological constant**
  Fukugita,M., Lahav,O. 1991 **Lyman-alpha at low redshift**
  Fukugita,M., Takahara,F., Yamashita,K., Yoshii,Y. 1990 **$m[z]$ in the blue band**
  Turner,Edwin L., Ikeuchi,Satoru 1992 **Evolution of forest density**
- **General discussion of observational points**
  Kauffmann,G., White,S.D.M. 1992
  Fukugita,M., Futamase,T., Kasai,M. 1990
  Lahav,O., Lilje,P.B., Primack,J.R., Rees,M.J. 1991
  Efstathiou,G., Sutherland,W.J., Maddox,S.J. 1990

QUASAR ABSORPTION FOREST: STRUCTURE

Density of absorbers along the line of sight:

$$\mathrm{d}N \propto \sigma \mathrm{d}\chi. \tag{2}$$

Evolution in number density

$$n[z]\mathrm{d}z = \sigma[z]\frac{\mathrm{d}z}{h[z]}. \tag{3}$$

Evolution in comoving size and cross-section

$$L_{\text{comoving}} = L_{\text{physical}}(1+z) = L_0 \; l[z] \; (1+z). \tag{4}$$

$$\sigma[z] = (1+z)^{2-d} l^{2-d}[z] \tag{5}$$

Evolution in number density

$$n[z] = n_0 (l[z](1+z))^{2-d} h^{-1}[z]. \tag{6}$$

Evolution of mass $m[z]$ and column density $s[z]$

$$m[z]\frac{\mathrm{d}z}{h[z]} = s[z](1+z)^{-2} n[z]\mathrm{d}z. \tag{7}$$

$$m[z] = s[z]n[z]h[z](1+z)^{-2}. \tag{8}$$

QUASAR ABSORPTION FORESTS: PHENOMENOLOGY

Evolution exponents

$$n[z] = (1+z)^{\gamma},\ \ l[z] = (1+z)^{\varepsilon},\ \ s[z] = (1+z)^{\sigma}, \tag{9}$$

$$m[z] = (1+z)^{\mu}, h[z] = (1+z)^{\nu}. \tag{10}$$

$$(\varepsilon + 1) \cdot (2 - d) = \gamma + \nu \tag{11}$$

$$\mu = \sigma + \nu + \gamma - 2 \tag{12}$$

Pressure-confined aggregates of fixed mass and temperature in an expanding hot gas environment

Duncan,R.C., Vishniac,E.T., Ostriker,J.P. 1991

Miralda-Escudé,Jordi, Rees,Martin J. 1993 **:**

$$3\lambda - d(\lambda + 1) = \begin{pmatrix} -5 & \textbf{adiabatic} \\ -3 & \textbf{isothermal} \end{pmatrix}. \tag{13}$$

The catalogues give

$$\begin{array}{ll} \gamma = 0.25 \ldots 5.7 & \text{mainly } \ 1.5 \ldots 2 \\ \sigma = 0.25 \ldots 1.7 & \text{I believe } \ 1 \ldots 1.5 \end{array}$$

QUASAR ABSORPTION FORESTS: CONCLUSIONS

- **Einstein-deSitter:** $\nu = 3/2$,

$$(\varepsilon + 1)(2 - d) = 1.75 \cdots 7.2, \text{ resp. } 3 \ldots 3.5 \tag{14}$$

$$\mu = 0 \ldots 7.4, \text{ resp. } 2.5 \ldots 3.5 \tag{15}$$

  That contradicts any model for the absorbers.

- **Approximately constant mass and absorbers not contracting yield**

$$\nu < 0 \tag{16}$$

- **sheet-like absorbers (bubble walls) yield in addition**

$$\nu = -\gamma \tag{17}$$

$\nu < 0$ for some time works only in a Friedmann-Lemaître universe with positive cosmological constant and curvature.

UNIVERSAL BUBBLE STRUCTURE

- **CfA survey**
  Geller,M.J., Huchra,J.P. 1991
- **Pancake scenario**
- **Domain walls**
  Nambu,Y., Ishihara,H., Gouda,N., Sugiyama,N. 1991
- **No voids seen in the line density**

Conclusion: The forest lines are the bubble walls itself
Bubble wall counts of

Liebscher,D.-E., Priester,W., Hoell,J. 1992

Liebscher,D.-E., Priester,W., Hoell,J. 1992

yield

$$\lambda_0 \approx 1.066,\ \kappa_0 \approx 0.08,\ \Omega_0 \approx 0.014 \tag{18}$$

$$z_{\min} \approx 3.5,\ h^2_{\min} \approx 0.4 \tag{19}$$

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