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PARTICLE-COSMOLOGY DESK COMPANION

R. A. Carrigan, Jr.

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> "If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties." Francis Bacon, as cited by P.W. Hodge; Ann. Rev. Astron. and Astrophysics, 19, 357 (81). Hodge then remarks, "The determination of the extragalactic distance scale, like so many problems that occupy astronomers' attention, is essentially an impossible task."

This is a list of some of the physical parameters that are often discussed in particle cosmology. The parameters have been assigned to the epoch where they have the most bearing (based on the compiler's understanding). The value of the parameter is given, along with a parenthetical comment about the relevance of the parameter. The references are contained in a separate parallel section.

Figure 1 is a copy of the fine chart of the history of the universe devised by J.D. Walker of Fermilab.

A postscript contains a short perspectus on the spirit of the compilation.

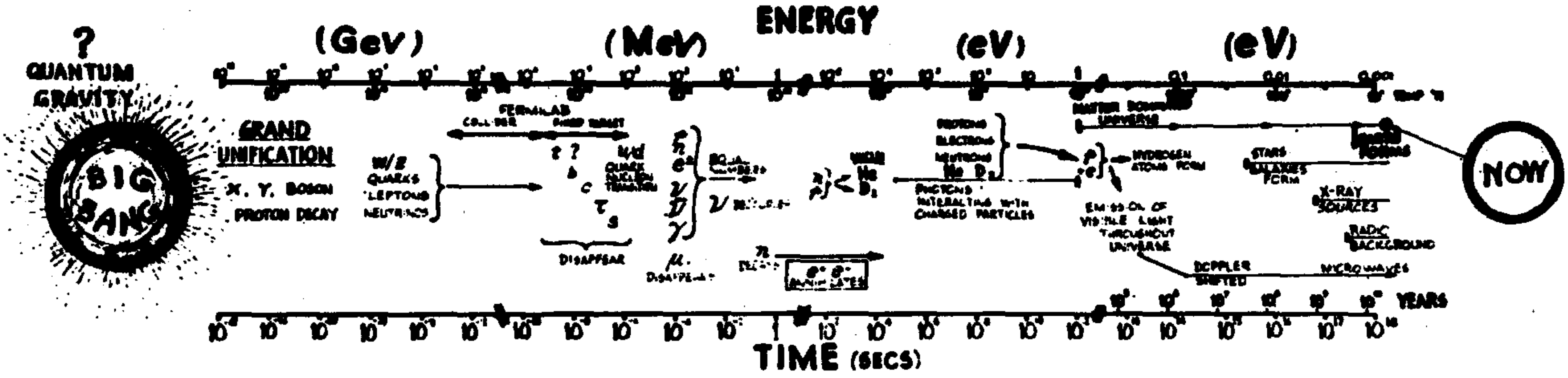

Figure 1. Walker chart showing the epochs in the evolution of the universe.

PLANCK EPOCH

Gravity wave background:

None with amplitude $>3*10^{-14}$, amplitude power spectral density $S_n = 10^{-27} f^{-1}$ (Hz^{1}) from spacecraft doppler wave detector ($\rho < 5*10^{-27}\mathrm{g/cm}^2$ for waves near $10^{-3}\mathrm{Hz}$). (Starobinsky suggests for de Sitter expansion at Planck time $\varepsilon(\nu) = 1.4*10^{-14}\ \nu^{-1}\ \frac{\mathrm{erg}}{\mathrm{cm}^3\mathrm{Hz}}$ and $n = 10^{-21}\nu^{-1}$ for the amplitude.)

GUT EPOCH

Minimal GUTs

Weinberg angle:

$\sin^2 \theta_w^e = 0.229 \pm .010$ (for $\rho = 1$).

$$(\sin \theta_w^t = \frac{3}{8} \{ 1 - \frac{\alpha}{4\pi} \frac{110}{9} \ln \frac{M^2}{Q^2} \} + ...$$

$$= 0.215 \pm .022$$

Baryon Asymmetry: (See also entropy, CP violation.)

No significant amount of antimatter within the solar system from a variety of observations. Less than 10^{-4} antistars/stars in the galaxy - based on galactic gamma ray luminosity. Matter prevails out to at least the galactic cluster. (CP violation allows matter-antimatter asymmetry.)

Entropy/baryon: (See also nucleosynthesis.)

$\gamma/n = (2 \pm .5) *10^9$ based on low z nuclear abundances. (Matter - antimatter annihilation enriches photon/baryon ratio. Small matter-antimatter difference makes the ratio large.)

Inflation

Isotropy and Large Scale Homogeneity: (See also cosmic photon background radiation.)

Unexplained angular variation is less than 1 part in 10,000 for cosmic background radiation over angular intervals separated by more than one degree after a local dipole asymmetry is factored out. (Inflation puts all parts of the universe in thermal equilibrium.)

Flatness: (See density.)

(The density of the universe is close to the critial density. Without inflation any departure from the critical density at GUT times would have been magnified enormously.)

Monopole Flux:

In an induction experiment, 1 monopole candidate was reported giving $f = 6*10^{-11}$ cm^{-2} s^{-2} sr^{-1}. Ionization experiments suggest much lower upper limits with $f < 1.5*10^{-14}$ cm^{-2} sr^{-1} s^{-1} reported at Baksan (95% confidence level). Galactic field suggests $f < 10^{-15}$ cm^{-2} sr^{-1} s^{-1}. If there is monopole catalysis at the strong interaction level $f < 5*10^{-22}$ cm^{-2} sr^{-1} s^{-1}. ("New" inflation suggests about 1 monopole/universe.)

Domain Walls:

No observational evidence in visible universe. (Inflation suggests that domain walls should be inflated away but still pass through every point in the universe during the life of the universe. Passage of a domain wall will radically change physics in the region.)

Strings:

No observational evidence.

Model Dependent Effects

Proton Decay:

$t_p > 10^{32}$ years - 90%CL for the $e\pi^+$ mode in water Cerenkov counter. (Minimal GUTS gives $2*10^{29 \pm 1.7}$. Note that this goes as Λ^4. Different GUTs change decay modes, e.g. supersymmetry favors K modes.)

Higgs Mass:

There is a lower bound of 10 GeV on the mass of the Higgs from the radiative correction formula. No cross section limits have yet been established. The Higgs meson is not expected to be heavier than O (1 TeV) because the self-coupling would become strong. (Sophisticated measurements of the Higgs numbers and masses at colliders could select between different GUTS.)

CP Violation, Super-Heavy Boson:

G_x is expected to be O (α) but is not known. Since this involves heavy quarks cannot be directly inferred from K^o - $\bar{K}^o$ violation which involves light quarks. (Minimal SU(5) gives a G_x that is far too small. Cosmological baryon asymmetry may indicate a more complicated GUT.)

Neutron Dipole Moment:

$|d| < 6*10^{-25}$ e-cm for Leningrad magnetic bottle experiment with 90% C.L. (In general CP violations from Higg's parameters are at the 10^{-24} level while those adding more quarks to the theory are at 10^{-28} where $d \overset{\sim}{>} 3*10^{-18}$ (n_b/n_γ) e-cm.)

Number of Neutrinos: (See electroweak.) (Number of neutrinos can select GUT.)

Gravitino and Photino:

For light case: $M > 4.3*10^{-7}$ eV from neutrino emission from white dwarfs and also ψ decay into unobserved neutrinos. Stable gravitino that saturates mass density gives $M < 1$ KeV. For heavy case: $M > 10^5$ GeV to maintain neutron-proton ratio. Presence of monochromatic photons in the cosmic background could indicate presence of gravitino or photino. (Existence of gravitino or photino suggests supersymmetry.)

Cosmological Constant:

$\Lambda/8\pi \ \varepsilon \leq 2*10^{-29}$g/cm^3 ($10^{-46}$ GeV^4) from universe expansion. (This number is small compared to other symmetry breaking mechanisms. Supersymmetry is sensitive to a cosmological term.)

Scale of Fluctuations: (See also isotropy and homogeneity.)

$\delta\rho/\bar{\rho} = 10^5$ for galaxies (10^{12} $M_\odot$), 10^2 for clusters, 1 for super clusters (10^{15} $M_\odot$). (To produce the present fluctuation levels, it is necessary for the fluctuation to be 10^{-4} when it enters the horizon.)

Spectrum of Fluctuations:

Galactic correlations are measured in terms of $\delta\rho/\rho$ or the autocorrelation function $\xi(r) = \langle\delta\rho(\bar{x} + \bar{r})\ \delta\rho\ (\bar{x})\rangle/\overline{\rho^2}$, the "over probablility" function where $\xi = 1$ means more than 2 times random. $\xi = a/r^\gamma$ where $\gamma = 1.77 \pm .04$ and there may be a change in γ near $r \approx 5$Mpc. (There are 3 common pictures of these fluctuations as a function of mass: 1) isothermal, where $\delta\rho/\rho|_{\text{decoupling}}$ goes as $M^{-1/2}$. This gives ξ but may not give large scale structure. These are too large in GUT inflation. 2) Neutrino fluctuations, where $\delta\rho/\rho|_{\text{matter}} \propto M^{-\alpha-2/3}$ and α is probably irrelevant. Large scale structure is all right while small scale structure is from fragmentation and may not work, 3) cold matter (axions, inos, etc.) where the spectrum is flat from galaxies to super-clusters and goes as $M^{-\alpha-2/3}$ above.

Shape:

There is no evidence for pancakes in super clusters. There is some evidence for voids on a scale of several hundred million light years. (The problem with the shape question, particularly voids and filaments, is the lack of an adequate statistic. Lack of pancakes is an argument against neutrinos.)

ELECTROWEAK EPOCH

Number of Neutrinos from ^{4}He Abundance: (See nucleosynthesis)

(The ^{4}He abundance requires that there be less than 4 neutrino species. In essence, the more light neutrinos, the faster the expansion, the larger n/p is, resulting in more ^{4}He.

Neutrino Mass Limits:

14 eV $< M_{\nu e} < 60$ eV from tritium decay. $M_{\nu\mu} < 0.57$ MeV (90% CL) from muon decay. Universe closure requires $\Sigma M_{\nu i} < 50$ eV. is also consistent with Fermi-Dirac statistics. Note that GeV mass neutrinos are also possible since they decouple earlier. These estimates are for infinite neutrino lifetimes. For finite lifetimes see Steigman chart. (Some GUTs predict massive neutrinos, e.g. O(10) suggests $M(\nu) \simeq 10$ eV.)

Majorana Neutrino Mass Limits:

Double beta decay experiments give upper limits of $\leq$ 12 ev at 68% CL (Some GUT theories suggest $M_\nu \sim M_q{}^2/M_x$ where M_q is a quark mass.)

Neutrino Mass Differences:

$\Delta^2_{\mu e} < M^2_{\nu\mu} - M^2_{\nu e} < 5$ eV^2, $\Delta^2_{\mu t} < 2.4$ eV^2. Reactor experiments in the 0.1 eV^2 to 5 eV^2 region are in disagreement. (Mass limits are related to mixing angles. Different GUTs suggest different mass difference possibilities.)

Z_o width :

No useful information yet from $\bar{p}p$ collider experiments. ($\Gamma(Z^o \to all) \simeq N_G$ (GeV) where N_G is the number of neutrino species. This may be observable.)

Neutrino Black Body Temperature:

(Neutrino temperature is expected to be $T = 2^o$ K.)

Neutrino density: (Expect 100 $\nu + \bar{\nu}/cm^3$ for each neutrino species. Number should be approximately the same as the photon density.)

CONFINEMENT EPOCH

Free Quarks:

A density of $2*10^{-20}$ charge 1/3 particles to nucleons has been reported in niobium balls in a magnetic levitation experiment. All other searches have produced null results including some at the level of $3*10^{-21}$ in iron. (Unconfined quarks created in the big bang would have survived to the present. An early estimate was $N_q/N_N \sim 6*10^{-10}/M_q$(GeV), much higher than the niobium estimate.)

Axions:

10^{-4} eV $< M_A < 10^{-2}$ eV. (The lower limit is a bound from universe closure, the upper bound is from evolutionary properties of red giants where there is He burning. Axions were introduced to solve the CP problem in QCD by introducing a complex pseudopotential.)

Ultrarelativistic Heavy Ions:

11 GeV/nucleon beams are needed in a ^{20} Ne + U collision to see a quark-hadron phase transition. Present heavy ion beam energies are below this. (When a phase change occurs, there should be more baryons to antibaryons and fewer pions.)

NUCLEOSYNTHESIS EPOCH

^{4}He Abundance: (See also electroweak.)

Y_p = ratio of helium mass in early universe = .245 ± .003. This is based on analysis of 13 dwarf galaxies where there should have been less heavy element processing. (The He^4 abundance depends on the relative abundance of neutrons and protons at 200s or temperatures around 1 MeV where $n/p = e^{-(m_n - m_p)/T}$. A precise value is predicted by standard cosmology.)

Neutron half-life

$\tau_n = 925 \pm 11$ sec. (The largest uncertainty in the theoretical estimate of the helium abundance is τ_n. Since the estimate of the number of neutrinos follows from this at the 1% level, it is significant.)

Deuterium abundance:

$D/H = 2*10^{-5}$ but with order of magnitude fluctuations from solar system observations of meteorites, solar winds and nearby interstellar medium. (D is only produced below 100 KeV. As n/γ is increased, amount of D decreases since burning becomes more efficient and He^3 is produced instead. This ratio suggests $n/\gamma < 10* 10^{-10}$.)

^{3}He abundance:

$^3He/H \cong (1-4)*10^{-5}$, based on meteoric, solar wind and some nearby stellar sources. (If the ratio $(D + {}^3H)/H < (6-10)*10^{-5}$ then $n/\gamma > 3-4*10^{-10}$.)

^{7}Li abundance:

$^{7}\mathrm{Li}/\mathrm{H} \lesssim 1.5*10^{-10}$ from extreme population II stars (old ones). (Element production above ^{7}Li does not occur in cosmology because there is no stable A = 8 isotope. For this ratio get $2*10^{-10} \leq n/\gamma < 5\text{-}7*10^{-10}$.)

PHOTON EPOCH

Photon black body temperature:

$T = 3.07 \pm 0.09^{\circ}K$ (1σ), primarily from balloon observations. (Note that the actual distribution with wavelength closely follows a black body distribution.)

Photon density:

$N_{\gamma} = 560$ photons/cm^3 (This follows directly from the black body temperature.)

Photon asymmetry: (See also isotropy.)

There is a dipole term of 2.99 ± .34 mK. There is no current evidence for a quadrupole term. (This temperature difference corresponds to a motion of the earth through the aether of 400 Km/sec.)

MATTER EPOCH

Hubble parameter:

H_o = 50-100 Km/s·Mpc, on the basis of redshift measurements (straightforward) and measurements of distances by a series of techniques that become progressively more difficult at greater distances. (Systematic uncertainties dominate this number. The range covers the dispersion between measurements. Measurements extend out to several hundred Mpc.)

Deceleration parameter:

$q_o^{obs} \simeq 0 \pm 1/2$, $q_o^{true} = q_o^{obs} + \Delta q_o^{evol}$ and Δq_o^{evol} uncertain to ± 1.) (q = $(q = \frac{1}{H^2}\left(-\frac{1}{a}\frac{d^2a}{dt^2}\right)$ is the dimensionless deceleration parameter. This is very difficult to measure but could decide the open vs. closed universe question.)

Universe lifetime:

t(globular clusters) = $(1-1.5)*10^{10}$ years from turn-off point of H-R curve in globular clusters, t(heavy isotopes, lower bound) = $(0.8-1.0)*10^{10}$ years, $t_H = 1/H = (1-2)*10^{10}$ years. (The correspondence between the first two times and the Hubble time indicates that the modern universe does date from the big bang.)

Critical density:

$\rho_c = (1.5 - 1.9)*10^{-29}$ g/cm^3, (This follows directly from the Hubble parameter since $\rho_c = 3H^2/8\pi G$)

Dark Matter:

Dark matter is usually reported in terms of a mass to light (luminosity) ratio, M/L, compared to the solar mass to light ratio.

System	M/L (Solar Units)	Density relative to critical density
Solar Neighborhood	2-4	$(0.0014-0.0029)h_o^{-1}$
Galaxies	$(8-20)h_o$	0.0057 - 0.014
Binary Galaxies & Sm. Grps.	$(60-180)h_o$	0.043 - 0.13
Large Clusters of Galaxies	$(280-840)h_o$	0.2 - 0.6
Hot Gas in Clusters	$(10-30)h_o^{-1/2}$	$(0.0071-0.021)h_o^{-3/2}$

(Even on the galactic level there is appreciable missing light and this effect increases for larger scales. Much of this evidence is based on galaxy rotation curves. Note that some of the measurements depend on the Hubble constant.)

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PLANCK EPOCH

Gravity Wave Background

a. Observation

R.W. Hellings et al., Phys. Rev. D23, 844 (81) and preceeding article.

b. Theory

A.A. Starobinsky, Phys. Lett 91B, 99 (1980), JETP Lett. 30, 682 (79).

GUT EPOCH

Minimal GUTs

Weinberg Angle

a. For a recent review see J.E. Kim et al., Rev. Mod. Phys. 53, 211 (81).

b. Other theoretical calculations - W. Marciano and A. Sirlin, Phys. Rev. Lett. 46, 163 (81) and also C. Jewellyn Smith et al., Nucl. Phys. B177, 266 (81).

c. Experimental value shown is from Berkeley blue book.

d. Ellis quotes 0.216 ± 0.012 with radiative corrections from W.J. Marciano and A. Sirlin, Phys. Rev. D22, 2695 (80), C.H. Llewellyn Smith and J.F. Wheater, Phys. Lett. 105B, 486 (81).

Baryon asymmetry

For a complete review see G. Steigman, Ann. Rev. Nuc. Sci. 14, 339 (76).

Entropy/baryon

Original references - S. Dimopoulous and L. Susskind, Phys. Rev. D18, 4500 (79).

M. Yoshimura, Phys. Rev. Lett. 41, 281 (78), D. Tousaint, S.B. Treiman, F. Wilczek and A. Zee, Phys. Rev. D19, 1036 (79), J. Ellis, M.K. Gaillard and D.V. Nanopoulus, Phys. Lett. 80B, 360 (79), S. Weinberg, Phys. Rev. Lett. 42, 850 (79).

Inflation

Isotropy

Best data seems to be cosmic background radiation. R. Sunyaev and Ya. B. Zel'dovich, Ann. Rev. Astron. and Astro. 18, 537 (80), R. Weiss, Ann. Rev. Astron. & Astro. 18, 489 (80). Dipole and quadrupole results are:

R. Fabbri et al., Phys. Rev. Lett. 44, 1563 (80). (Note: This does not contain a direct analysis showing that the dipole term is due to the peculiar motion.)

Monopole flux

See Magnetic Monopoles, R. Carrigan and W.P. Trower, Ed., Plenum (1983) or R. Carrigan, W.P. Trower, Nature, 305, 673 (83).

Domain walls

Strings

Model Dependent Effects

Proton Decay

R.M. Bionta et al., Phys. Rev. Lett 51, 27 (83).

Higgs Mass

a. For a short review see J. Ellis et al., Ann. Rev. Nuc. Sci. 32, 443 (82).

$$M_H^2 = \frac{3\alpha^2}{8\sqrt{2}\,G_p}\left[\frac{2 + \mathrm{Sec}^4\theta_w}{\sin^4\theta_w} - O\left(\frac{m_f}{m_w}\right)^4\right]$$

is a formula for radiative corrections.

CP Violation

A good place to see how ε_x should go is:

D.V. Nanopoulos and S. Weinberg, Phys. Rev. D20, 2484 (79).

(Problem is intrinsic vs spontaneous violation.)

Neutron Dipole Moment N. Ramsey, Ann. Rev. Nucl. and Part. Sci. 32, 211 (82). The measurement of D is from Leningrad as cited by Ramsey, I.S. Altarev et al., Phys. Lett 102B, 13 (81). The relation for d in terms of n_b/n_γ is from Turner, NSF-ITP-81-65 (81) citing J. Ellis et al., Phys. Lett. 99B, 101 (81).

Gravitino and photino

See H. Pagels in "Gauge Theories, Massive Neutrinos and Proton Decay," A. Perlmutter, Ed., Plenum (81), for summary.

$m > 10^{-8}$ eV - P. Fayet, Phys. Lett. B84, 421 (79).

$m \sim 4.3*10^{-7}$ eV - M. Fukugita and N. Sakai, Phys. Lett. B114, 23 (82).

$m \lesssim 1$ KeV - H. Pagels and J.R. Primack, Phys. Rev. Lett. 48, 223 (82).

$m > 10^5$ GeV - S. Weinberg, U. Texas (1982).

D. Sciama - IAAS Trieste 18/82/A (82) may summarize evidence on monochromatic photon background.

Cosmological Term

a. H. Pagels in "Gauge Theories, Massive Neutrinos and Proton Decay," A. Perlmutter, ed., Plenum (81) says something on how supersymmetry bears on this term.

b. F. Wilczek, NSF-ITP-83-13, p. 27, gives another view on this using a dynamical approach.

Scale of fluctuations

Material cited is from M. Turner, 1983 Aspen Early Universe Workshop. For comments on the horizon question see:

a. Y.B. Zeldovic, MNRAS 160, 1P (1972).

b. J.R. Gott and M.J. Rees, Astron. Astrophys. 45, 365 (1975) as cited by Pagels.

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Shape

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ELECTROWEAK EPOCH

Number of neutrinos from He^4 abundance

V. Schvatzman, JETP Lett. 9, 184 (69). G. Steigman, D. Schramm, J. Gunn, Phys. Lett. 66B, 202 (77) (as cited by Wilczek).

Neutrino mass limits

Tritium decay - V. Lubinov et al., Phys. Lett. B94, 266 (80).

Muon Neutrino Mass - M. Daum et al., Phys. Rev. D20, 2692 (79).

Observation on the sum of masses - D. Schramm and G. Steigman, Ap. J. 243, 1 (81). See also P. Frampton and P. Vogel, Phys. Rep. 82, 342 (82). Finite lifetime effects - See D. Schramm - EFI 81-03 - Fig. 1.

For situation on heavier masses see G. Steigman, Ann. Rev. of Nuc. & Part. Phys. 29, (79), also B. Lee and S. Weinberg, Phys. Rev. Lett. 39, 165 (77). M.H. Shaevitz, Invited Talk, 1983 Lepton-Photon Symposium, Columbia (Nevis) (1983).

Marjorana neutrino mass limits

W.C. Haxton, G.J. Stephenson, Jr., and D. Strottman, Phys. Rev. Lett. 47, 153 (81). This contains an up-to-date theoretical discussion of double β decay and uses Russian value as finite mass for normal neutrino.

E. Fiorini, Nuovo Cimento A13, 747 (73) give $\tau^{0\nu}_{1/2} = 5*10^{21}$ yr for ^{76}Ge.

M. Gell-Mann, P. Ramond, R. Slansky (unpublished) 1974.

B.T. Cleveland et al., PRL 35, 737 (75) for no neutrinos in ^{82}Se give $\tau^{0\nu}_{1/2} \geq 3.1*10^{21}$ yr.

Neutrino mass differences

P. Frampton and P. Vogel, Phys. Rep. 82, 342 (82). This is a complete review of the question of massive neutrinos. It includes a summary of many recent searches. Some accelerator experiments and one reactor experiment have suggested positive contributions.

Z_0 width

J. Ellis et al., Ann. Rev. Nuc. and Part. Sci. 32, 443 (82).

Neutrino black body temperature

See D.N. Schramm, EFI 81-03 (81) for an explanation.

Neutrino density

See F. Wilczek, NSF-ITP-83-13 (1983) for estimate.

CONFINEMENT EPOCH

Free quarks

For a review see L. Jones, Rev. Mod. Phys. 49, 717 (77). A recent report of the Fairbank experiments is in G.S. LaRue, et al., Phys. Rev. Lett. 46, 967 (81), Ya. B. Zeldovic, L.B. Okun, and S.B. Pikelner, Phys. Lett 17, 164 (65).

Axions

Lower mass limit: See H. Pagels, RU 83/B/49 (83).

For summaries: See J. Preskill et al., Phys. Lett. 120B, 127 (83); L.F. Abbott and P. Sikivie, Phys. Lett. 120B, (83); M. Dine and W. Fischler, Phys. Lett. 120B, (83) plus fact $M_A = M_\pi f_\pi / v$ where $m_\pi = .14$ GeV, $f_\pi = .9$ GeV and v is the vacuum expectation value $\langle\phi_A\rangle_o = Ve^{i\theta}$ and $v < 10^{12}$ GeV.

Upper mass limit:

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NUCLEOSYNTHESIS EPOCH

^{4}He abundance

See, for example, Proceedings of the ESO Workshop on Primordial Helium, P.A. Shaver, D. Kunth and K. Kjär. (83).

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Deuterium abundance

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^{3}He abundance

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J. Geiss and H. Reeves, Astron. & Astrophys. 18, 126 (72).

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^{7}Li abundance

M. Spite and F. Spite, Astron. and Astrophys. 115, 357 (1982). Comments from Steigman article above.

PHOTON EPOCH

Photon black body temperature

D.P. Woody, et al., Phys. Rev. Lett 34, 1036 (75) with lowest error bars.

For a general recent review see:

R. Weiss, Ann. Rev. Astron. & Astrophys. 18, 489 (80).

For a review of the theoretical foundations see:

R.R. Sunyaev and Ya. B. Zeldovic, Ann. Rev. Astron. and Astrophys. 18, 537 (80).

Photon Density

Can get via $N_\gamma = 550\theta/\text{cm}^3$

(See Sunyaev and Zeldovic noted above.)

Photon assymetry

E.S. Cheng et al., Astrophys. J. Lett. 232, L139 (79).

G.F. Smoot, et al., Phys. Rev. Lett. 39, 898 (77).

Original evidence for a quadrupole term was R. Fabbri et al., Phys. Rev. Lett. 44, 1563 (80), but is apparently outdated.

MATTER EPOCH

Hubble parameter

A recent review is:

P. Hodge, Ann. Rev. Astron. and Astrophys., 19, 357 (81).

There is not a single most representative value of the Hubble parameter.

Deceleration parameter

G. Steigman, Aspen Workshop on the Early Universe, 1983.

Universe Lifetime

Globular clusters:

I. Iben, AAS Symposium on the Age of the Universe, Toronto (1981).

For a summary on heavy isotope lifetimes see:

E. Symbalisty, D. Schramm, Rep. Prog. Phys. 44, 293 (1981). Remarks are from F. Wilczek, NSF-ITP-83-13.

Critical density

This is just a formula.

Dark matter

For a review see:

S.M. Faber and J.S. Gallagher, Ann. Rev. Astron. & Astrophys., 17, 135 (79).

The table is taken from G. Steigman, p.67, "Astrophysics and Elementary Particles, Common Problems." Ed. N. Cabibbo, et al, Acc. Naz. Dei Lincei, (80).

Postscript

Struck by D. Schramm's Physics Today article (Apr, 1983) emphasizing the links between cosmology and particle physics, I set out several months ago to flesh out his list of experiments with a set of measurred values for each quantity. I was strongly influenced by the wonderful Berkeley wallet cards for particle physics that first appeared nearly a quarter of a century ago. (Some then unborn or still in the muhling and puking stage at that time may not realize that the present blue book used to be no more than a credit card in size.) A few afternoons of trying to put measurements and references to Schramm's list soon showed systematic errors that spanned a factor of two.

This is in no way a criticism of a very industrious and ingenious set of measurements. Rather it is meant to emphasize the fact that it is not possible to characterize many of the particle-cosmology parameters with a few critical experiments in the way most ordinary particle physics parameters are.

Cowed by this I have often been reduced to citing review articles as a basis for a parameter.

I am acutely conscious that there are probably many errors of interpretation, fact, and citation in this material. I would appreciate being educated. If I find that there are several friends of the Desk Companion, my plan is to attempt an update in some months based on the corrected information, hopefully in concert with more qualified astronomers and physicists.

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