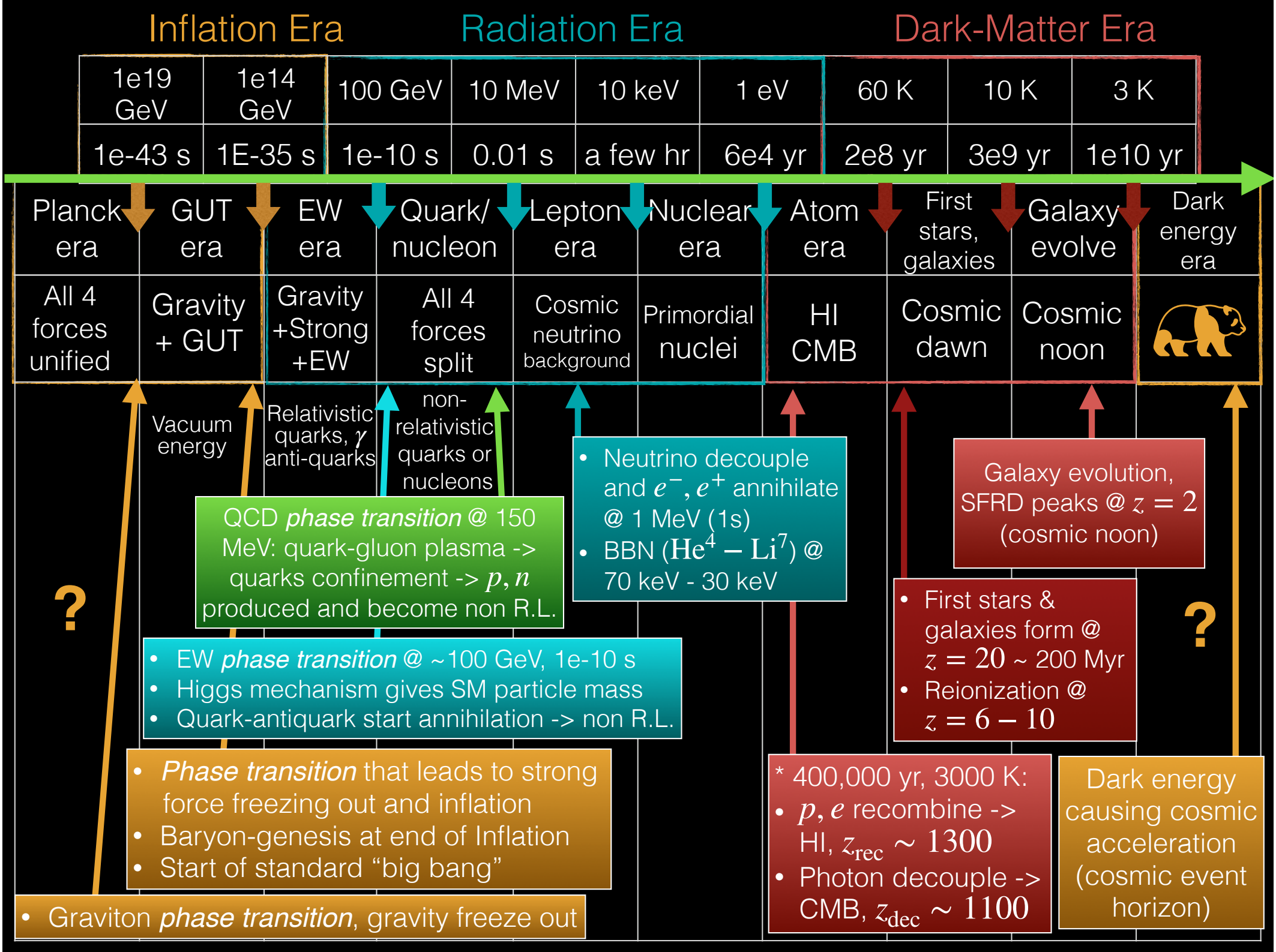
Inflation Era
Radiation Era
Dark-Matter Era
1e19 GeV
1e14 GeV
100 GeV
10 MeV
10 keV
1 eV
60 K
10 K
3 K
1e-43 s
1E-35 s
1e-10 s
0.01 s
a few hr
6e4 yr
2e8 yr
3e9 yr
1e10 yr
Planck era
GUT era
EW era
Quark/ nucleon
Lepton era
Nuclear era
Atom era
First stars, galaxies
Galaxy evolve
Dark energy era
All 4 forces unified
Gravity + GUT
Gravity +Strong +EW
All 4 forces split
Cosmic neutrino background
Primordial nuclei
HI CMB
Cosmic dawn
Cosmic noon
Vacuum energy
Relativistic quarks, γ anti-quarks
non-relativistic quarks or nucleons
?
QCD phase transition @ 150 MeV: quark-gluon plasma -> quarks confinement -> p, n produced and become non R.L.
• Neutrino decouple and e⁻, e⁺ annihilate @ 1 MeV (1s)
• BBN (He⁴ – Li⁷) @ 70 keV - 30 keV
Galaxy evolution, SFRD peaks @ z = 2 (cosmic noon)
• First stars & galaxies form @ z = 20 ~ 200 Myr
• Reionization @ z = 6 – 10
?
• EW phase transition @ ~100 GeV, 1e-10 s
• Higgs mechanism gives SM particle mass
• Quark-antiquark start annihilation -> non R.L.
• Phase transition that leads to strong force freezing out and inflation
• Baryon-genesis at end of Inflation
• Start of standard “big bang”
* 400,000 yr, 3000 K:
• p, e recombine -> HI, z_rec ~ 1300
• Photon decouple -> CMB, z_dec ~ 1100
Dark energy causing cosmic acceleration (cosmic event horizon)
• Graviton phase transition, gravity freeze out

| Era | Epoch | Time (after Big Bang) | Density (kg/m$^3$) | Temperature (K) | Main Events |
|---|---|---|---|---|---|
| *Radiation Era* | | | | | |
| | Planck | 0 s | $\infty$ | $\infty$ | Unknown physics; quantum gravity. |
| | | $10^{-43}$ s | $10^{95}$ | $10^{32}$ | 1E19 Gev |
| | GUT* | | | | Strong, weak, and electromagnetic forces unified. |
| | | $10^{-35}$ s | $10^{75}$ | $10^{27}$ | *Inflation + reheating produce particles* |
| | Quark | | *Sea of Quarks and anti-Quarks* | | Strong force frozen out. Heavy and light particles all in thermal equilibrium. Electroweak force freezes out at $10^{15}$ K. |
| | | $10^{-4}$ s | $10^{16}$ | $10^{12}$ | 100 Mev |
| | Lepton | Proton and neutron out of thermal equilibrium ~ MeV: (1) neutrino decouple at 1s (C$\nu$B: 1.95K @ today); (2) neutron decay; (3) e and e+ annihilation, heat up photon background temperature | | | |
| | | $10^{2}$ s | $10^{4}$ | $10^{9}$ | 100 kev |
| | Nuclear | | | | *BBN (Helium+ form)@ first 3 min; photons fall out of chemical equilibrium @ 1 day* |
| | | $5 \times 10^{4}$ yr ($2 \times 10^{12}$ s) | $6 \times 10^{-16}$ | 16,000 | |
| *Matter Era* | | | | | |
| | Atomic | $5 \times 10^{4}$ yr ($2 \times 10^{12}$ s) | $6 \times 10^{-16}$ | 16,000 | *Recombination (hydrogen form) @ 400,000 yrs, CMB photons escape (CMB: 3K @ today)* |
| | Galactic | $2 \times 10^{8}$ yr ($6 \times 10^{15}$ s) | $10^{-22}$ | 60 | Large-scale structure forms; first stars and quasars shine; galaxies form and grow. |
| | | | *Re-ionization (z~6-10)* | | |
| | Stellar | $3 \times 10^{9}$ yr ($10^{17}$ s) | $2 \times 10^{-25}$ | 10 | Galaxies merge and evolve; star formation peaks. Dark energy begins to dominate. |
| *Dark Energy Era* | | $>10^{10}$ yr ($3 \times 10^{17}$ s) | $3 \times 10^{-27}$ | 3 | |