Future History of the Universe
“In the space of one hundred and seventy-six years the Lower Mississippi has shortened itself two hundred and forty-two miles. That is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Silurian Period, just a million years ago next November, the Lower Mississippi River was upwards of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.”

Mark Twain
Life on the Mississippi
Now

The universe is 13.7 billion ($1.37 \times 10^{10}$) years old
15 Gyr: (1 billion years from now). The Solar luminosity has increased to the point where the average temperature on Earth reaches the boiling point of water. *It may be time to move to cooler climes!*

19 Gyr: (5 billion years from now). The Sun leaves the main sequence. Its radius approaches one AU. Mercury is vaporized. Planets spiral outwards as the red giant Sun loses mass in a solar wind. Venus may survive; the Earth ends up near where Mars is now.
• **21 Gyr**: (7 billion years from now). The Sun becomes a white dwarf.

• $10^{12-13}$ yrs: The faintest, lowest mass stars burn out and become white dwarfs. Also, galaxies in clusters merge together.

• $10^{13-14}$ yrs: There are no luminous stars in the universe. The *stelliferous era* has come to an end, and we enter the *degenerate era*.

• $10^{14}$ yrs: Universal expansion has carried all galaxies out of sight. It is a lonely universe.

• $10^{14-33}$ yrs: All matter is in black holes, neutron stars, white dwarfs, brown dwarfs, and planets.

• $10^{16-20}$ yrs: Collisions strip planets from stars, and eject stars from galaxies. Central black holes in galaxies grow.
• $10^{14-20}$ yrs:
  o Binary stars spiral together and merge.
  o Collisions between white dwarfs produce supernovae.
  o Collisions between brown dwarfs produce low mass stars.
  o Typical galaxies shine with one solar luminosity.

• $10^{20}$ yrs: The only luminosity in the universe comes from white dwarfs absorbing dark matter. White dwarfs glow at a temperature of 64K.

• $10^{33-37}$ yrs: The end of matter. Protons decay. White dwarfs glow with a luminosity of 400 Watts.
• $>10^{60}$ yrs: The Black Hole era.
  o $10^{65}$ yrs: Stellar mass black holes evaporate.
  o $10^{100}$ yrs: Galactic mass black holes evaporate.

• If $w = -1.5$, the universe will be ripped apart (the Big Rip) in 35 billion years.
  Big Rip timeline (Caldwell et al., Phys Rev Letters, August 15 2003)
    o $T_0 - 60$ million years: the Milky Way is torn apart.
    o $T_0 - 3$ months: the solar system becomes unbound.
    o $T_0 - 30$ minutes: the Earth explodes.
    o $T_0 - 15$ seconds: atoms are pulled apart.
Otherwise

This is how the world will end. Not with a bang, but a whimper.

After $10^{100}$ years, the universe is a dilute and ever-expanding gas of photons, neutrinos, electrons, and their antiparticles. Eventually all particles annihilate with their antiparticles.

This timeline has been adapted, in part, from
• *The Future of the Universe*, by F.C. Adams and G. Laughlin, Sky and Telescope, August 1996, pg. 32, and from