I have “collected” (stolen) liberally from everyone. see, for example Sean Carroll’s  http://preposterousuniverse.com/writings/cosmologyprimer/
our milky way
>200 billion stars, 100,000 ly diameter

Hubble, 1929: we are 1 galaxy in a universe of galaxies
sloan sky survey
supermassive black hole at the center

http://www.mpe.mpg.de/ir/GC/index.php
This Chandra image of the supermassive black hole at our Galaxy's center, a.k.a. Sagittarius A* or Sgr A*, was made from the longest X-ray exposure of that region to date. In addition to Sgr A* more than two thousand other X-ray sources were detected in the region, making this one of the richest fields ever observed.
Einstein’s theory of general relativity: a theory of gravity beyond Newton gives an equation for the evolution of the universe

“The supreme task of the physicist is to arrive at those universal elementary laws from which the cosmos can be built up by pure deduction.” (Albert Einstein, 1954)
matter-energy determines geometry
Dark Matter + Dark Energy affect the expansion of the universe

\[ \Omega_m, \Omega_v \]

- 0.3, 0.7
- 0.3, 0.0
- 1.0, 0.0
- 5.0, 0.0

Relative size of the universe vs. Billions of Years

Billions of Years:
- -10
- Now
- 10
- 20
- 30

Relative size of the universe:
- 0
- 1
- 2
- 3
- 4
the universe is expanding
Hubble's 1929 data
light from distant sources is red-shifted by expansion so as to appear as if they are receding

OBJECT RECEIVING: LONG RED WAVES

OBJECT APPROACHING: SHORT BLUE WAVES
distance versus red shift

the universe is expanding
the universe is 13.7 +/- 0.2 Gyr (13.7 billion) years old
Supernovae “type Ia”

standard candles
SN1994D, a Type Ia supernova at the edge of a distant galaxy
distance versus red shift
with linear expansion divided out:
expansion is accelerating
The Big Bang

Early universe was hot and dense. Light from the early universe cools as the universe expands. Gamov predicted in 1948 that this cosmic background radiation should be observable.
Discovery of CMB by Penzias and Wilson (1965)
Isotropy of the Cosmic Microwave Background
Temperature of universe now = 2.735 K
we are moving at 600 km/s with respect to primordial radiation
temperature fluctuations as revealed by COBE
artist’s conception of WMAP
Temperature fluctuations measured by WMAP
the universe is flat
DISTRIBUTION OF DARK MATTER IN NGC 3198

\[ V_{\text{cir}} \text{ (km/s)} \]

\[ \text{Radius (kpc)} \]

NGC 3198

disk

halo
Einstein ring: gravitational lensing
Inferred dark matter (blue) surrounding a cluster of galaxies
“bullet” galaxy composite image
can we directly detect the dark matter?
predicting and measuring the composition of primordial atoms
SNe: Knop et al. (2003)
CMB: Spergel et al. (2003)
Clusters: Allen et al. (2002)