= anow today and a =
athen previously) . This yields
<formula>
which can be rewritten as
<formula>
Using the definition of redshift provided above , the equation
<formula>
is obtained . In an expanding universe such as the one we inhabit , the scale factor is monotonically increasing as time passes , thus , z is positive and distant galaxies appear redshifted .

Using a model of the expansion of the Universe , redshift can be related to the age of an observed object , the so @-@ called cosmic time ? redshift relation . Denote a density ratio as ?0 :
<formula>
with ?crit the critical density demarcating a universe that eventually crunches from one that simply expands . This density is about three hydrogen atoms per thousand liters of space . At large redshifts one finds :
<formula>
where H0 is the present @-@ day Hubble constant , and z is the redshift .

= = = = Distinguishing between cosmological and local effects = = = =

For cosmological redshifts of z < 0 @.@ 01 additional Doppler redshifts and blueshifts due to the peculiar motions of the galaxies relative to one another cause a wide scatter from the standard Hubble Law . The resulting situation can be illustrated by the Expanding Rubber Sheet Universe , a common cosmological analogy used to describe the expansion of space . If two objects are represented by ball bearings and spacetime by a stretching rubber sheet , the Doppler effect is caused by rolling the balls across the sheet to create peculiar motion . The cosmological redshift occurs when the ball bearings are stuck to the sheet and the sheet is stretched .

The redshifts of galaxies include both a component related to recessional velocity from expansion of the Universe , and a component related to peculiar motion (Doppler shift) . The redshift due to expansion of the Universe depends upon the recessional velocity in a fashion determined by the cosmological model chosen to describe the expansion of the Universe , which is very different from how Doppler redshift depends upon local velocity . Describing the cosmological expansion origin of redshift , cosmologist Edward Robert Harrison said , " Light leaves a galaxy , which is stationary in its local region of space , and is eventually received by observers who are stationary in their own local region of space . Between the galaxy and the observer , light travels through vast regions of expanding space . As a result , all wavelengths of the light are stretched by the expansion of space . It is as simple as that ... " Steven Weinberg clarified , " The increase of wavelength from emission to absorption of light does not depend on the rate of change of a (t) [here a (t) is the Robertson @-@ Walker scale factor] at the times of emission or absorption , but on the increase of a (t) in the whole period from emission to absorption . "

Popular literature often uses the expression " Doppler redshift " instead of " cosmological redshift " to describe the redshift of galaxies dominated by the expansion of spacetime , but the cosmological redshift is not found using the relativistic Doppler equation which is instead characterized by special relativity ; thus v > c is impossible while , in contrast , v > c is possible for cosmological redshifts because the space which separates the objects (for example , a quasar from the Earth) can expand faster than the speed of light . More mathematically , the viewpoint that " distant galaxies are receding " and the viewpoint that " the space between galaxies is expanding " are related by changing coordinate systems . Expressing this precisely requires working with the mathematics of the Friedmann @-@ Robertson @-@ Walker metric .

If the Universe were contracting instead of expanding , we would see distant galaxies blueshifted by an amount proportional to their distance instead of redshifted .

= = = Gravitational redshift = = =

In the theory of general relativity , there is time dilation within a gravitational well . This is known as the gravitational redshift or Einstein Shift . The theoretical derivation of this effect follows from the Schwarzschild solution of the Einstein equations which yields the following formula for redshift associated with a photon traveling in the gravitational field of an uncharged , nonrotating , spherically symmetric mass :

<formula>

where

G is the gravitational constant ,

M is the mass of the object creating the gravitational field ,

r is the radial coordinate of the source (which is analogous to the classical distance from the center of the object , but is actually a Schwarzschild coordinate) , and

c is the speed of light .

This gravitational redshift result can be derived from the assumptions of special relativity and the equivalence principle ; the full theory of general relativity is not required .

The effect is very small but measurable on Earth using the Mössbauer effect and was first observed in the Pound ? Rebka experiment . However , it is significant near a black hole , and as an object approaches the event horizon the red shift becomes infinite . It is also the dominant cause of large angular @-@ scale temperature fluctuations in the cosmic microwave background radiation (see Sachs @-@ Wolfe effect) .

= = Observations in astronomy = =

The redshift observed in astronomy can be measured because the emission and absorption spectra for atoms are distinctive and well known , calibrated from spectroscopic experiments in laboratories on Earth . When the redshift of various absorption and emission lines from a single astronomical object is measured , z is found to be remarkably constant . Although distant objects may be slightly blurred and lines broadened , it is by no more than can be explained by thermal or mechanical motion of the source . For these reasons and others , the consensus among astronomers is that the redshifts they observe are due to some combination of the three established forms of Doppler @-@ like redshifts . Alternative hypotheses and explanations for redshift such as tired light are not generally considered plausible .