Curvature Cosmology

A Model for a Static, Stable Universe

David F. Crawford

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Preface

This book describes a new cosmological model. It is based on two major hypotheses, curvature-redshift, and curvature-pressure and the complete model is called curvature-cosmology. Also included are tests of the hypotheses that are based on non-cosmological observations.

There are no observations that refute the model. My objective is to present a new theory and thus topics are covered only to the extent that they have a bearing on the theory. For example, in many cases I have chosen what I think are the most recent and best sets of data to the exclusion of earlier results. I apologise to those authors whose work is thereby omitted.

The development of this book has taken many decades and I have received valuable input from many colleagues in the Astrophysics Department, School of Physics, University of Sydney. Unfortunately, the passage of time prevents full acknowledgement of their contributions. However, I would like to thank Dr Tony Turtle who has patiently listened to many of my hypotheses and has provided valuable criticism and encouragement. All of the analysis has been done using the Linux operating system and I am very grateful to all those programmers who have made it such a stable and useful system. The graphics have been done using the DISLIN plotting library provided by Helmut Michels at the Max-Plank-Institut in Lindau.

The advent of the internet and the use of NASA's Astrophysics Data System has greatly facilitated this work by providing access to most of the published literature in astronomy. It is equivalent to having a major library on one's desk. This research has made use of the NASA/IPAC Extragalactic Database (NED) that is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Finally, I wish to thank my wife June whose patience and help I greatly appreciate.

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1 Introduction

Theories of the universe date back to the dawn of civilisation. Since the advent of Einstein's theory of general relativity in 1915, there has been a major upsurge in the application of physics to cosmology. At present, the dominant cosmological model is known as the 'Big-Bang'. It is based on an unstable solution of the equations of general relativity such that the Hubble redshift is explained as due to expansion of spacetime. A major characteristic of Big-Bang theory is its flexibility, enabling it to accommodate observations with ad hoc additions, but at the same time making it a theory that is difficult to refute. Although Big-Bang cosmology has had considerable success in explaining many astronomical observations, it sometimes does so by way of additions such as inflation, dark matter, and quintessence. Such additions make it an inelegant theory. Despite this, Big-Bang cosmology is currently the dominant paradigm and nearly all analyses of cosmological observations use it either directly or indirectly.

Curvature cosmology is a complete cosmology that is presented as an alternative to the Big-Bang model. Scientifically it is a much better theory as listed below.

- It is elegant and mathematically much simpler.
- It is refutable.
- It obeys the perfect cosmological principle of being uniform in both space and time.
- It is additional to general relativity and quantum mechanics and does not require any changes to either theory.
- For homogeneous plasma, it has one free parameter – the density.
- Hubble's constant is determined by the density.
- It predicts an accurate value for the temperature of the X-ray background radiation.

- It predicts an accurate value for the temperature of the microwave background radiation.
- There is excellent agreement with many cosmological observations without the need to invoke ad hoc additional hypotheses such as evolution and dark matter.
- It can explain many minor observations such as the K-effect for bright stars.
- It accurately predicts the observed rate for the solar neutrino flux.
- It can explain the Pioneer 10 anomalous acceleration.
- A laboratory test of curvature-redshift is possible.

Apart from the initial hypotheses of curvature- redshift and curvature-pressure there are no other hypotheses needed to achieve excellent agreement with observations.

What is offered here is a cosmological theory that has an elegant structure and does not need any ad hoc additions. As a consequence, its predictions are unambiguous and the theory is potentially refutable by observational evidence. This new theory stands or falls on its own merits. Nevertheless, in testing it by comparing predictions with observations, it is often necessary to make references to Big-Bang cosmology. There are two reasons for this: one is because some observations have been carried out on the basis of demonstrating some aspect of Big-Bang cosmology, such as the search for dark matter; the second is because any new theory will necessarily need to demonstrate that the fit of the new theory to observations is superior to that of the dominant paradigm, and thus specific comparisons need to be made.

This new theory is based on two major hypotheses. The first is that the Hubble redshift is due to an interaction of photons with curved spacetime. In this sense, it is a tired-light model. The second is that there is a pressure that acts to stabilise expansion and provides a static stable universe. These two effects are called curvature-redshift and curvature-pressure. The cosmology based on these effects is hereafter referred to as curvature-cosmology. These effects do not change either general relativity or quantum mechanics: they are explicitly added to both theories.

There are two major parts to this book. The first part describes the two hypotheses of curvature-redshift and curvature-pressure and then develops curvature-cosmology. The second part examines all the relevant cosmological data in the context of the resultant cosmological model. There is excellent agreement between the predictions and the observations. More importantly, there are no observations that refute the model. In all cases the model explains the observations as well as or much better than does the Big-Bang model.

Further applications of the hypotheses in non-cosmological contexts lead to findings that curvature-pressure can explain the solar neutrino rate deficiency. Many experiments have measured the solar neutrino flux and it is observed to be about 50% of the rate predicted by the standard solar model.

Observations of Pioneer 10 and some similar spacecraft have shown that they are consistently slowing down in a manner that is consistent with a very small acceleration towards the sun. Curvature-redshift can explain the Pioneer 10 acceleration anomaly as being due to a redshift from inter-planetary dust interacting with Doppler radar analysis.

Chapter 2 provides an overview by describing how the universe would appear in this new curvature-cosmology. The essential difference from Big-Bang cosmology is that the universe is stable, static and statistically the same at all places and at all times. It obeys the ‘perfect cosmological principle’. Thus in curvature-cosmology there is no origin of the universe. In curvature-cosmology, the Hubble constant is merely a scale factor between redshift and distance and its reciprocal, which has the dimensions of time, has no relevance as an age.

The new hypothesis of curvature-redshift for photons is presented in chapter 3. The basic hypothesis is that the redshift arises from an interaction between the photons and curved spacetime. Energy is lost in each interaction to very low-energy secondary photons. A secondary hypothesis is that curvature-redshift is inhibited if there are other interactions whose mean free path is less than that for the gravitational interaction. The dominant inhibiting interaction is refractive index. The effect of curvature-redshift on other particles is also considered.

In order to observe curvature-redshift in the laboratory we need to have sufficient density of gas (or plasma) to achieve a measurable effect but not enough for there to be inhibition by the refractive index. An experiment using the Mössbauer effect for γ rays is discussed that could show the effects of curvature-redshift in a laboratory. It is shown that it is possible to measure the redshift and to detect the secondary radiation that is produced by curvature-redshift.

Chapter 4 is about curvature-pressure and uses an argument that gravitation is acceleration and not a force. Curvature-pressure has a universal application that is essential to the development of curvature-cosmology. It also has a local application that is important in explaining why the neutrino production rate in the sun is much lower than expected.

The following chapter uses the equations of General Relativity modified by the inclusion of curvature-pressure to derive the geometry of a stable static universe. It is essentially Einstein's static model with the addition of curvature-pressure, which makes it stable and finite. A very interesting consequence of the model is that it predicts that the cosmic plasma has a very high temperature of 2.56×10^9 K which agrees with observations. Another result of curvature-cosmology is that it predicts that the Hubble constant is proportional to the square root of the average density of the universe. The working equations for luminosity, angular size, and surface brightness as a function of the redshift z are derived.

The topics of entropy, Olber's Paradox, and nuclear abundances are also discussed. The model for nuclear abundances is that heavy nuclei are destroyed in the high temperature cosmic plasma to get an approximately equilibrium mix of hydrogen and helium. This collapses in sequence to clouds, clusters of galaxies, galaxies, and then stars where there is a recombination to heavier nuclei. This material is then recycled back to the cosmic plasma. The topics of black holes and astrophysical jets are briefly covered.

Chapter 6 is devoted to examining the observational evidence with two objectives in mind. The first objective is to ascertain what support there is for curvature-cosmology. However, more importantly the second objective is to see if there is any unambiguous evidence that refutes curvature-cosmology. The chapter starts with an analysis of the background X-ray observations. These are especially important in that they provide estimates of the average density and the plasma temperature. The results are in excellent agreement with curvature-cosmology.

The next topic of type 1a supernovae could be problematic in that it is generally agreed that the observations show strong evidence of time dilation due to universal expansion which is definitely contrary to curvature-cosmology. It is argued that there are strong selection effects on the observations and that, given this, the results are in excellent agreement with curvature-cosmology.

Observations show that the time scales for quasar variability are independent of redshift. This is clearly contrary to Big-Bang cosmology but in agreement with curvature-cosmology.

The distribution of the linear size of distant objects has never been satisfactorily explained in Big-Bang cosmology. However, curvature-cosmology provides a simple explanation that is in excellent agreement with observations. Next, the observed value of the Hubble constant is compared with the predicted value and again excellent agreement is found.

Because of the close relationship between luminosity and apparent area that holds in curved spacetime, observations of surface brightness provided a very important cosmological test. Currently the observations are incomplete. Nevertheless, they show strong support for curvature-cosmology.

A major argument for dark matter comes from applying the virial theorem to clusters of galaxies. Given the velocity dispersion of the galaxies, the virial theorem predicts the average mass of the galaxies. Since the predicted mass is one or two orders of magnitude larger than that predicted by their luminosities, the concept of dark matter was introduced to account for the discrepancy. In curvature-cosmology, it is shown that the discrepancy arises because the redshift dispersion has been wrongly ascribed to velocity dispersion. Curvature-redshift in the inter-galactic gas produces a redshift that is much larger than the Doppler effect of their velocities. The observed redshift dispersion is predominantly due to curvature-redshift in the inter-galactic gas. The agreement of the theory with the observations is excellent and many other velocity-related effects are also explained.

The dense spectrum of absorption lines seen in the spectra of distant quasars is ascribed to Lyman-alpha absorption in intervening clouds of gas. This is one topic where there could be serious problems for curvature-cosmology. Because of curvature-redshift within these clouds the line widths and hence the apparent absorption depths can be quite different from those derived from usual astrophysics. Hence, the full interpretation of the lines will require an analysis starting from the original spectra. What is found is that the distribution of these lines as a function of redshift does not fit the predictions. However, this distribution is extremely sensitive to the strength of the lines and since curvature-redshift cast doubts on most of the strengths this discrepancy requires a more detailed investigation.

One of the important aspects of Big-Bang cosmology is that there must be evolution, which is evidenced by change in average characteristics of objects as a function of redshift. Evolution is often invoked to explain discrepancies between observations and predictions in a rather ad hoc manner. In chapter 7 we examine the problem of evolution for galaxies in general where it is shown that with proper regard to strong selection effects there is no evidence for evolution. The next topic covered in chapter 7 is the distribution of quasar magnitudes. It is shown that in curvature-cosmology they have a well-defined distribution with a well-defined peak. This is at odds with Big-Bang cosmology where the quasar density distribution is still increasing at the faintest magnitudes. No evidence is found for evolution in the quasar data.

Many argue that one of the long-standing pieces of evidence for evolution is the Butcher-Oemler effect. This is that after corrections for band shifts, distant galaxies are bluer than nearby ones. However, recent reviews of the research literature show that the effect is not consistent and probably does not exist.

The counting of radio sources as a function of their flux density has a long history going back to the 1950s. In fact, these observations were one of the main reasons for rejecting the steady state theory of Bondi, Gold and Hoyle. Curvature-cosmology can explain all the major aspects of the distributions for a wide range of radio frequencies. This analysis provides strong evidence for the validity of the theory.

Chapter 8 covers some topics that investigate the support for curvature-redshift and curvature-pressure independent of cosmology. In Big-Bang cosmology, dark matter is used to explain the anomalous rotation curves of galaxies. In curvature-cosmology, the observations are due to a true rotation curve plus a larger curvature-redshift that is due to the halo of gas around the galaxy. The next topic is to consider the effects of curvature-redshift in our own Galaxy. For radio frequencies, the inhibition of curvature-redshift by refractive index will occur. That is, most of the radio frequency redshifts are correctly interpreted as velocities and the dynamic description of the Galaxy will be unchanged. However if there is a Galactic object that is observed at both radio and optical wavelengths the redshifts could differ. Observation of such an object that showed discrepant redshifts would provide strong support for curvature-redshift.

Even closer to home is the topic of solar neutrinos, or more particularly why is there a deficiency in their observed rates? It is shown that curvature-pressure will act to help support the solar atmosphere so that the thermodynamic pressure and hence the temperature will be less. The predicted neutrino rates are in excellent agreement with the observations. It is also shown that curvature-redshift falls short by about six orders of magnitude as an energy source for the inner solar corona. However, it may have a part to play in heating the galactic corona.

The final topic in chapter 8 is that of the anomalous acceleration of Pioneer10. In this case, there is a complex interaction between the results of curvature-redshift due to the inter-planetary dust and the navigation programs that could explain the acceleration with a plausible density of inter-planetary dust.

Chapter 9 provides a brief summary of how well the hypotheses espoused here stand up to the scrutiny of observations.

This book is the culmination of many years of work and is a complete re-synthesis of many approaches that I have already published. Because hypotheses and notations have changed and evolved, direct references to these earlier attempts to describe the theory would be misleading. Table 1 (all with author D. F. Crawford) is provided briefly stating each reference and the major topic in each paper. In nearly all cases, the data analysed in the papers has been superseded by the more recent data that are analysed in this book.

Table 1: Published papers

Year	Reference	Major topic	
1975	Nature, 254, 313	First mention of photon extent and gravity	
1979	Nature, 277, 633	Photon decay near the sun: limb effect	1
1987	Aust. J. Phys. 40, 440	First mention of curvature-redshift	2
1987	Aust. J. Phys. 40, 459	Application to background X-rays	
1991	Astrophys. J. 377, 1	More on curvature-redshift and applications	
1993	Astrophys. J. 410, 488	A static stable universe: Newtonian cosmology	
1995	Astrophys. J. 440, 466	Angular size of radio sources	
1995	Astrophys. J. 441, 488	Quasar distribution	
1999	Aust. J. Phys. 52, 753	Curvature-pressure and many other topics	

Notes:

1. Not only is the theory discredited but also the observations have not stood the test of time.
2. This gives the equation for photons but not for non-zero rest mass particles.

1.1 Other Phenomena

In Big-Bang cosmology, there are a number of basic problems and, from time to time problems posed by new data. Big-Bang cosmology is formulated in such a way that these problems can be overcome by ad hoc additions to the theory. Curvature-cosmology does not require these additions, and is formulated in such a way that good observational evidence could potentially falsify the theory. The following paragraphs briefly describe problems that occur in Big-Bang cosmology but do not occur in curvature-cosmology.

Big-Bang cosmology has two basic problems that arise directly from the Friedmann equation. The first is the flatness problem. If the Friedmann equation is to describe a universe of the age it supposedly has, the average density must be very close to the critical density. To obtain our present universe, then at nuclear synthesis, for example, when the Universe was around 1s old, we require that the ratio of average density to critical density must be (Liddle & Lyth 2000) equal to unity to one part in $10^{16.}$ Such accuracy is unlikely to occur by chance.

The second problem is related to homogeneity of the Universe. Called the horizon problem, it arises because microwaves coming from regions separated by more than the horizon scale at last scattering, which typically subtends about a degree, cannot have interacted before decoupling (Liddle & Lyth 2000). Then why is it that the temperature of microwave radiation coming from quite different parts of the sky is so accurately the same? Guth (1981) introduced the concept of inflation as a cure for these ills. Because curvature-cosmology is stable, static and finite, it has no need for inflation.

There are three main reasons for suggested occurrence of dark matter. The first one is that since the density of observed matter is less than the critical density, there must be some unseen material that makes up the shortfall. Since critical density has no special significance in curvature-cosmology, there is no need to postulate dark matter to satisfy this shortfall. The second reason is that the quantity of matter in clusters of galaxies that is derived from using the virial theorem and the redshifts of the galaxies is much larger than the observed quantity inferred from luminosities. The third reason is to explain the anomalous rotation curves of spiral galaxies. In curvature-cosmology, both these latter observations are explained by curvature-redshift. That is the anomaly is not due to excess mass but because all of the redshift was ascribed to peculiar velocities. In a similar vein, dark energy has been suggested as a cause for the apparent acceleration of the rate of expansion of the universe. As discussed later not only is the expansion zero, there is no evidence for ‘acceleration’ so that dark energy (or anything else such as quintessence) is not needed.

Black holes have been a very interesting theoretical construct for many decades and many claim that there is considerable observational evidence for their existence. However, all of this evidence is indirect with the most compelling evidence being X-rays and other radiation coming from accretion disks. The evidence for the mass of black holes comes from redshifts from nearby stars and gas. However if most of these redshifts are due to curvature-redshift in the surrounding gas, these mass estimates would be considerably decreased. One consequence of curvature-pressure is that it will prevent a compact object denser than a neutron star from completely collapsing to a black hole. Instead, there would be a very dense object with a size between a neutron star and a black hole. This object would be surrounded by an accretion disk. Thus, observations interpreted as a being due to a black hole could be observations of such an object.

1.2 Other alternative theories

After reading a draft version of this book Professor Jean-Claude Pecker suggested that it would be enhanced by a comparison with other alternative theories that try to explain the Hubble redshift and other cosmological observations. Much of the early work has been reviewed by Ellis (1984). More recently Peebles (1993) provides an even handed summary. Ghosh (1991) has a list of non-velocity redshift mechanisms that have been suggested from 1919 to 1986. The majority of these alternative cosmological models are of little relevance to curvature-cosmology since they require a different or modified gravitational theory, whereas curvature-cosmology is strongly based on general relativity.

Alternative redshift theories that are or may be relevant to curvature-cosmology can be classified as tired-light theories. These have the major characteristic that as photons propagate they lose energy by some form of interaction with another particle such that the energy loss rate is proportional to the photon energy. The essential difference between these theories is in defining the type and properties of such particles. The major objection to these theories has been that the interaction will also produce an angular scattering of the photons (Zel'dovich 1963, Schatzman 1970) which is not observed.

Pecker & Vigier (1987) propose an interaction between a massive photon and vacuum particles that avoids the scattering problem. LaViolette (1986) starts from a field theory which he calls subquantum kinetics that predicts that photons travelling through intergalactic space, where the gravitational field potential is least negative, should gradually decrease their energy. Since the magnitude of the scattering is inversely proportional to the mass of the interacting particle he escapes the scattering problem by, in effect, having the photons interact with the gravitational field that has no recoil momentum so that there is no scattering. This is similar to the way in which curvature-redshift avoids the scattering problem.

A different approach has been taken by Marmet (1988, see also Marmet & Reber, 1989). He argues that the energy loss is via very low energy photons lost by bremsstrahlung during normal electromagnetic (Compton) interactions. He further argues, with support from Jauch & Rohrlich (1980), that even in 'elastic' scattering there is production of these very low energy photons. His estimate of the density of gas required to produce the Hubble redshift is about 2.5×10^4 hydrogen atoms m^{-3}, which is about 10^4 times the density, found by curvature-cosmology. Finally, he argues that the angular scattering is small enough to pass the scattering test.

Ghosh (1991) has considered a process that is based on Sciama's model for inertial induction (see section 5.7.5). Sciama added an acceleration dependent term to the Newtonian gravitational equation in his investigations of the origin of inertia. Ghosh extends this by adding a velocity dependent term. The result is a cosmic drag force that could explain the Hubble redshift. Since it is a simple drag, there is no scattering and thus no blurring of distant objects. He calls his theory velocity-dependent inertial induction and also applies other redshifts and planetary phenomena. Overall it is an interesting extension of Sciama's ideas.

Many other mechanisms such as electromagnetic and plasma interactions and photon decay have been proposed but it is difficult to find a model that provides an energy-loss rate that is proportional to the photon energy and also solves the scattering problem. By comparison, it will be shown that curvature-redshift has better agreement with current observations and it will occur in many more situations where redshifts are observed.

2 Overview of curvature cosmology

2.1 The new hypotheses

This chapter provides a qualitative description of curvature-cosmology and describes how it leads to a model of the universe that is static and stable. Thus, the major difference from Big-Bang cosmology is that there was no beginning to the universe and there is no evolution of the universe and definitely no expansion. Although there is evolution of stars and galaxies, the statistical properties of the universe are the same at all places and at all times. Hence, curvature-cosmology obeys the 'perfect cosmological principle'.

2.2 Curvature-redshift

The first hypothesis is that the redshift in the spectral lines that is observed in distant galaxies and quasars is due to a gravitational interaction. In this respect is a tired-light theory. The essence of the hypothesis is that the passage of a photon through curved space-time can be described as being the same as that for a bundle of geodesics. Then, if space-time is curved, the cross sectional area of this bundle of geodesics will change along the trajectory. For positive mass and energy, the change will be a decrease in area, a phenomenon that is described by the 'focussing theorem' (Misner, Thorne, & Wheeler, 1973). The curvature-redshift hypothesis is that characteristics of the photon, in particular the angular momentum, are computed by volume integrals and, if the scale size (as determined by the geodesic bundle) changes, then these characteristics must change. However, quantum mechanics requires that the value of the angular momentum be fixed. This leads to an impasse that is resolved by an interaction between the photon and curved spacetime. What happens is that from time to time, as determined by the uncertainty principle, the photon splits into one photon with most of the energy and two very low-energy photons. It is the loss of energy to these secondary low-energy photons that produces the observed redshifts. Although not strictly correct, it is convenient to consider the photon with most of the energy as being the continuation of the original photon but with a slightly reduced energy. Note that there must be at least two secondaries in order to conserve spin. Furthermore, on grounds of symmetry, it is hypothesised that the two secondaries are emitted in opposite directions so that there is no deviation in the 'primary' photon's trajectory.

One of the major objections to tired-light explanations (Zel'dovich 1963) for the redshift has been that if the energy loss were due to an interaction of a photon with a particle there would be angular scattering of the original photon. A typical type of interaction would be Compton scattering of the photons off charged particles. The observations of point images of very distant quasars show that this angular scattering is not observed. For curvature-redshift, there are two reasons why such scattering is expected to be negligible.

The first is that the interaction is between the photon and curved spacetime, the effective mass of which is very much larger than that of any atomic particle, and since the size of the angular scattering is inversely proportional to the scattering particle's mass the angular scattering is very small. The second reason is that it is hypothesised that the emission of the secondaries is symmetric, with zero transverse momentum that results in no deflection of the 'primary' photon.

It is shown below that for most astrophysical applications the energy loss rate and hence the redshift is proportional to the square root of the density of the medium. This result follows directly from using the 'focussing theorem' and General Relativity. This redshift mechanism is called curvature-redshift in order to distinguish this redshift from other redshifts such as those due to velocity and gravitation. The first test of General Relativity was the observation of the angular deflection of photons whose trajectory passed near the limb of the sun. Obviously, we might ask whether this deflection is accompanied by a decrease in energy. The answer is that under the hypothesis of curvature-redshift there is no predicted energy loss that would be observed as a redshift. What happens is that the cross sectional area of the geodesic bundle has its shape distorted but there is no change in its area and therefore no predicted curvature-redshift. There is however the prediction of a very small redshift due to the density of plasma in the solar corona.

Since quantum mechanics shows that particles, such as electrons and protons, can be considered as waves, curvature-redshift will apply to them in a similar manner. The only difference from photons is that the change in cross sectional area uses the geodesic equations appropriate for massive particles.

2.3 Curvature-pressure

If the redshifts of quasars and distant galaxies are due to curvature-redshift and not due to universal expansion then it is reasonable to consider static cosmological models. Although we could consider an expanding universe that includes curvature-redshift, this complication should be considered only if demanded by observations. The Einstein static cosmology, which has the same geometry as the expanding model but without expansion, has a serious defect. It is intrinsically unstable. Any slight perturbation will cause the universe to either expand or contract. Thus, any viable cosmological model that is static must address this issue. My second major hypothesis does this by introducing curvature-pressure. This not only solves the stability problem but leads to a cosmological model that is in excellent agreement with observations.

Consider the pressure at the bottom of a column of water in the ocean. Usually we ascribe the pressure as being due to the gravitational attraction of the earth acting on the water column. Now assume that the bottom is removed and the identical column of water is in free fall. There is no change whatsoever in the gravitational attraction, but the pressure has gone. This shows that the pressure is actually due to elastic forces in the bottom counteracting the acceleration due to gravity. These elastic forces are distributed throughout the earth so that the whole earth experiences the reaction force to the weight of the column of water. This thought experiment suggests that whenever a non-gravitational force opposes a gravitational acceleration there is the possibility of a pressure. For Newtonian gravity whenever some material is not in free fall there must be a pressure (or force) present. In General Relativity the concept of free fall is the same as that of geodesic motion. That is a particle with negligible mass is in ‘free fall’ if it follows a geodesic.

Now consider a very large volume of gas with uniform density, which determines the local curvature of spacetime. Except for particle-particle collisions, the gas particles follow geodesics and the collisions produce the usual thermodynamic pressure. There are no other forces and hence no additional pressure. However, suppose that the gas is partially or fully ionised plasma. Since the electro-magnetic forces between the particles produce accelerations that are very many orders of magnitude stronger than gravitational accelerations, the charged particles do not travel along geodesics. The hypothesis of curvature-pressure is that since the particles are no longer travelling along geodesics there is a pressure generated by the non-geodesic motion. In this case, the reaction to these non-geodesic accelerations is a curvature-pressure that is acting on the matter producing curved spacetime in such a way as to try to decrease the curvature. The pressure must act in this way or else there would be a runaway effect and violation of conservation of energy. In other words, the plasma produces curved spacetime through its density entering the stress-energy tensor in Einstein’s field equations and the magnitude of the curvature increases with increasing density. Then the failure of the particles in the plasma to follow geodesics produces a pressure that acts to decrease the curvature and hence decrease the density of the plasma. In Newtonian terminology, the curvature-pressure opposes the mutual gravitational attraction of the plasma particles. It must be emphasised that although curvature-pressure acts and has many similar properties to thermodynamic pressure it is quite distinct. For example, there is no curvature-pressure in a neutral gas.

2.4 The Cosmological Model

The simplest cosmological model is a universe containing plasma with uniform density. The curvature-cosmology model is Einstein’s static solution to the equations of General Relativity with the addition of curvature-pressure. This solution is described by the Friedmann equations with an additional term that describes the effects of curvature-pressure. It is the curvature-pressure that stabilises the static solution.

One of the remarkable results of curvature-cosmology is that it has one free parameter, which can be taken to be the average density of the universe. It is convenient to express this density as the equivalent number of hydrogen atoms per cubic metre. That is, define $N=\rho/m_{\mathrm{H}}$, where ρ is the density and m_{H} is the mass of a hydrogen atom. Not only does the density determine the size of the universe it also determines the Hubble constant. For example with, N=2 m^{-3} we find that it predicts the Hubble constant to be H=59 $\mathrm{km.s^{-1}.Mpc^{-1}}$. Furthermore, curvature-cosmology predicts that the plasma has a very high temperature (2.56×10^{9} K). It is interesting to note that this temperature is independent of the density of the universe.

The basic cosmological model is one in which the cosmic plasma dominates the mass distribution and hence the curvature of spacetime. In this first order model, the gravitational effects of galaxies are neglected. The geometry of this curvature-cosmology is that of a three-dimensional surface of a four-dimensional hypersphere. It is almost identical to that for Einstein's static universe. For a static universe, there is no ambiguity in the definition of distances and times. One can use a universal cosmic time and define distances in light travel times or any other convenient measure. Furthermore, curvature-pressure makes the solution stable.

Curvature-cosmology makes quite specific predictions that can be refuted. Curvature-cosmology obeys the perfect cosmological principle of being homogeneous in space and constant in time. Thus, any observations that unambiguously show changes in the universe with redshift would invalidate curvature-cosmology.

In curvature-cosmology, there is a continuous process in which some of the cosmic plasma will aggregate to form galaxies and then stars. The galaxies and stars will evolve and eventually all their material will be returned to the cosmic plasma. Thus, a characteristic of curvature-cosmology is that although individual galaxies will be born, live and die, the overall population will be statistically the same for any observable characteristic.

3 Derivation of curvature-redshift

3.1 Introduction

The derivation of curvature-redshift is based on the fundamental hypothesis of Einstein's General Theory of Relativity that spacetime is curved. As a consequence, the trajectories of initially parallel point particles, geodesics, will move closer to each other as time increases. Consequently the cross sectional area of a bundle of geodesics will slowly decrease. In applying this idea to photons, we assume that a photon is described in quantum mechanics as a localised wave where the geodesics correspond to the rays of the wave. Note that this wave is quite separate from an electromagnetic wave that corresponds to the effects of many photons. It is fundamental to the hypothesis that we can consider the motion in spacetime of individual photons. Because the curvature of spacetime causes the focussing of a bundle of geodesics, this focussing also applies to a wave. As the photon progresses, the cross sectional area of the wave associated with it will decrease. However, in quantum mechanics properties such as angular momentum are computed by an integration of a radial coordinate over the volume of the wave. If the cross sectional area of the wave decreases, then the angular momentum will also decrease. However, angular momentum is a quantised parameter that has a fixed value. The solution to this dilemma is for the photon to split into two very low-energy photons and a third that has the same direction as the original photon. It is convenient to consider the interaction as a primary photon losing a small amount of energy into two secondary photons. Averaged over many photons this energy loss will be perceived as a small decrease in frequency.

Since in quantum mechanics electrons and other particles are considered as waves, a similar process will also apply. It is argued that electrons will interact with curved spacetime to lose energy by the emission of very low-energy photons.

3.2 Photons in Curved Spacetime

Einstein's General Theory of Relativity requires that the metric of spacetime be determined by the distribution of mass (and energy). In general this spacetime will be curved such that in a space of positive curvature nearby geodesics that are initially parallel will come closer together as the reference position moves along them. This is directly analogous to the fact that on the earth lines of longitude come closer together as they go from the equator to either pole. In flat spacetime, the separation remains constant. For simplicity, let us consider geodesics in a plane. Then the 'equation for geodesics deviation' can be written (Misner, Thorne, & Wheeler, 1973, p 30) as

$$\frac{d^2\xi}{ds^2} = -\frac{\xi}{a^2} \tag{1}$$

where ξ is normal to the trajectory and s is measured along the trajectory. The quantity $1/a^2$ is the Gaussian curvature at the point of consideration. For a surface with constant curvature, that is the surface of a sphere, the equation is easily integrated to get (ignoring a linear term)

$$\xi = \xi_0 \cos(s/a) \tag{2}$$

Note that this equation also describes the separation of lines of longitude as we move from the equator to either pole. Now geodesics describe the trajectories of point particles. Null-geodesics are associated with mass-less particles. However, photons are not point particles. The experiment of using single photons in a two-slit interferometer shows that individual photons must have a finite size.

Quantum mechanics requires that all particles are described by wave functions and therefore we must consider the propagation of a wave in spacetime. Because photons are bosons, the usual quantum mechanical approach is to describe the properties of photons by creation and destruction operators. The emphasis of this approach is on the production and absorption of photons with little regard to their properties as free particles. Indeed because photons travel at the speed of light, their lifetime in their own reference frame between creation and destruction is zero. However, in any other reference frame they behave like normal particles with definite trajectories and lifetimes. Havas (1966) has pointed out that the concept of a single photon is rather tenuous. There is no way we can tell the difference between a single photon and a bundle of photons with the same energy, momentum, and spin. However, it is an essential part of this derivation that a single photon has an actual existence.

Assume that a photon can be described by a localised wave packet that has finite extent both along and normal to its trajectory. This economic description is sufficient in the following derivation. We define the frequency of a photon as $\nu = E/h$ and its wavelength as $\lambda = hc/E$ where E is its energy. These definitions are for convenience and do not imply that we can ascribe a frequency or a wavelength to an individual photon; they are properties of groups of photons. The derivation requires that the wavelength is short compared to the size of the wave packet and that this is short compared to variations in the curvature of spacetime. Furthermore, we assume that the rays of any wave follow null geodesics and therefore any deviations from flat spacetime produce change in shape of the wave packet. In other words, since the scale length of deviations from flat space are large compared to the size of the wave packet they act as a very small perturbation to the propagation of the wave packet.

Consider a wave packet moving through a spacetime of constant positive curvature. Because of geodesic deviation, the rays come closer together as the wave packet moves forward. They are focussed. In particular the direction θ, of a ray (geodesic) with initial separation ξ_0 after a distance s is (assuming small angles)

$$\theta = -\frac{s\xi_0}{a^2} \tag{3}$$

where a is the local radius of curvature. Since the geodesic is the direction of energy flow, we can integrate the wave-energy-function times the component of θ normal to the trajectory, over the dimensions of the wave packet in order to calculate the amount of energy that is now travelling normal to the trajectory. The result is a finite energy that depends on the average lateral extension of the wave packet, the local radius of curvature, and the original photon energy. The actual value is not important but rather the fact that there is a finite fraction of the energy that is moving away