Comparing Cosmological Models.

Andrew Holster. ATASA Research. 2022.

Introduction.

The *standard model of cosmology* is acclaimed in physics as accurate, robust, well-tested, our best scientific theory of the cosmos, "the primary theory of the universe" (Lambda-CDM model - Wikipedia). Its picture of the universe is routinely presented as established scientific fact. It is taken for granted by many academics and science commentators. But it has had serious anomalies for a while, including the *Hubble tension, anomalous galaxies*, and *the completely unexplained nature of dark energy* and *dark matter.* And lurking behind it all is the lack of a unified theory: General Relativity (GR) and quantum mechanics (QM) are inconsistent. We have known for some time that something is seriously missing from our fundamental theories.

Now startling new observations by the James Webb Space Telescope (JWST) in 2022 of the early universe present the strongest challenge yet to the standard model, and whispers have started that this shows there is something wrong with the fundamental theory, General Relativity itself, that it all rests on. This would be a crisis for cosmology, because it has been locked into this theory for decades. Practically all models considered or tested in conventional cosmology are variations of GR Friedmann (FLRW) models. If it is wrong, the theorists have been on a wild goose-chase for decades: and they have no ideas for an alternative.

But how could it be wrong? Isn't the standard model *scientifically tested?* Cosmologists talk a lot about *testing their theories*, and they report thousands of tests of cosmological models. (Lee, 2022). However, we should realise that these are just *computer simulations of variations of the standard FLRW theory.* They are about comparing different *models* of the theory, to try to find the *model* that best fits the somewhat scanty data. Physically, the models represent different mixtures of stuff appearing in the evolution of the universe at different times, including ordinary matter and radiation, black holes, dark matter, dark energy, the cosmological constant. A combination of these is included in the favoured ΛCDM model, and other speculative models include other combinations, including different types of exotic matter. Key interest lies in getting stars and galaxies to form at the right times in the simulations, while keeping the expansion rate of the universe consistent with the empirical data on the Hubble constant.

But the point is that *these are not tests of GR or the FLRW theory against any alternative theory.* Physicists have not considered alternatives to GR for a long time. GR and the FLRW equations have long been taken for granted, as the theoretical bedrock of cosmology. The major effort in cosmology has been *to find best-fitting parameters for the FLRW equations,* to fit sparse empirical data to what theorists are already convinced is the correct fundamental theory. Cosmologists (e.g. Panotopoulos, 2019; Lee, 2022) claim that the *ΛCDM model* is a very good fit with the data, and infer this provides strong empirical evidence for the theory. In particular, they claim it is strong evidence for *dark energy,* which the *ΛCDM model* requires.

But now with the new JWSP data, the standard cosmology has hit an empirical rock! It has been making predictions about *unobserved realms*, including early star or galaxy formation, around 300 My after the Big Bang – but this realm has now suddenly become observable, and *it doesn't look anything like what the theory predicts!* Indeed, it is so far from the model simulations that the question is whether the standard theory can survive. It is not just the *ΛCDM model* under threat, but *the entire framework of GR and the FLRW equations* that the new data brings into question.

But how could the physicists be so wrong, if they have *scientifically tested the ΛCDM theory* so carefully? We should realise that mainstream cosmology has only been testing *models of the standard theory* against each other. They have established that models with dark energy (the *ΛCDM* model) work better than models without it. But this is only a weak verification of the general theory itself, i.e. the FLRW equation or GR. And there are few tests of it except against classical gravity. The problem is that if we want to *test a theory*, we really need an *alternative theory* to test it against, to give us some idea of where it may go wrong. But very few cosmologists think GR *is* wrong! Most can hardly credit the possibility that it could be wrong, and they have not tried to develop any alternatives to GR.

I note that the main alternative to GR that has been proposed is MOND, or Modified Newtonian Gravity. (Milgrom, 1988). This postulates that the gravitational force acts differently on the large scale. It is rejected by most cosmologists because it appears too *ad hoc,* but it has supporters, and is still being tested. But there are only weak tests, and it has problems as a theory (Skordis and T. Złośnik, 2021). However, MOND is not in itself a *cosmological theory*. Nor is it a fundamental theory. It does not propose any consistent alternative to replace the *metric theory* of GR or the FLRW. It's chief motivation is to dispense with *dark matter,* but otherwise it just adopts the general framework of conventional physics. It has implications for cosmology, but it is not at all clear what they are. It is presented as an *instrumentalist theory*. We present a quite different type of alternative, which is a fundamental theory which must be evaluated *counterfactually*, with inter-theoretic transformations. It is very definite, and much simpler to analyse. We do not discuss MOND further here.

Here we compare the standard cosmology with an alternative fundamental theory, that has a strikingly different overall cosmological behaviour: a simple cyclic expansion function. It is simple and deterministic. There are only two or three general parameters. The interesting result is that this alternative cosmology: (A) closely matches the expansion observed and modelled through the ΛCDM standard model, now going back to red-shifts of 5-15; and (B) it also predicts unexpected early galaxy formation now being reported by the JWST.

The first result (A), matching *expansion curves,* is a modelling exercise that we simulate in a simple spreadsheet. There is an *empirical coincidence* between the expansion rates predicted by two models. It also reflects similar mathematical shapes of intervals of two quite different curves. The early-mid interval of the cyclic *sin-squared solution* we introduce looks like the *FLRW solution* for the same interval. The latter is a polynomial with just enough parameters to *model this section of the sin-squared function* accurately.

This shows that *the empirical data is far too weak to determine what the true general expansion function is.* Data on expansion rates (Hubble parameter) cannot distinguish between *the standard model*, and our *simple cyclic solution*. The second results (B) reflect a change in the fundamental physics. The theory means gravity was stronger in the past. This requires a separate evaluation of physics, not given here. But it was obtained from a *unified theory,* which supports its consistency with quantum mechanics, and expanded version of general relativity.

The aim here is to support this alternative theory as a serious possibility, and a kind of possibility that has been overlooked by the highly instrumentalist approach taken in modern physics, which has made this theory invisible. However, we are not concerned to try to prove it here. We only review the cosmological evidence, mainly related to the new JWST data, as a comparison with the standard theory. We do not review the whole theory, which extends to gravity and quantum mechanics. Some essential theory is given in Appendices, but the background is given elsewhere. The main purpose here is to present the key concepts and results as directly as possible.

Philosophers will recognise a close parallel with themes made famous by (Kuhn, 1962), including inter-theoretic translatability of facts or laws, and the problem of how much theory choice is influenced by conceptual models versus empirical data. Indeed Kuhn's (1957) example of the Copernican Revolution, the first great modern cosmological revolution, has direct parallels with the present situation. The standard cosmological theory appears as like the *Ptolemaic theory*, with endless potential for *ad hoc* fixes to keep it matching anomalous data, while the alternative is a much simpler general law. We do not discuss this further here, but it provides a detailed example of the same kind of problem.

What's wrong with this picture?

Figure 1. The Standard Model of Cosmology. WIKIPEDIA. We have seen this picture plastered across the cosmologist's narrative for years. It is meant to be the definitive picture of the universe. What's wrong with it? Well, lots of problems have emerged, but most recently, in 2022 the JWST imaged *galaxies fully formed by 300-600 million years after the Big Bang!* Now that is an unbelievably short period for galaxies to form. The standard model has long claimed that *the first stars* would just be forming in this time. Galaxies should take a billion years more. This has been shown in many computer simulations of the standard model.

The claim that the *first stars would only be appearing at about 400 Mys* has long been assumed as *a fact of cosmology*, but now it turns out to be false. It is clear it represents theoretical speculation. Failed speculation. Clearly the standard theory has been extrapolated to a realm *where it does not work*. The standard model predictions *for the first few hundred million years* bears little resemblance to reality. Prior to the JWST observations in 2022, there were limited observations of this early period, and cosmologists had no suspicion of anything wrong. Now they have a swag of new data, and a severe problem with their theory. The early universe is full of *galaxies* that require billions of years to form in simulations. How could these form so fast?

That is one key question for us, and it is closely connected with others. How did the universe start? And how is it going to end? And what is the mysterious appearance of dark energy in-between? We have been given a cartoon of this, presented as scientific fact, but it is time for us to question it.

As the Hubble Space Telescope, Planck and other sources have given us more precise data over the last decades, we are seeing more empirical departures from the standard model. But so far, astronomical data has been primarily used to optimise the standard model, to select parameters to make it fit the observations as well as possible. *Dark energy* has been added to keep it working. The last fifty years of effort *has been primarily to make the standard model work*.

But now it appears increasingly flawed, and we want to examine the standard model. We cannot just keep blindly pursuing it as the only theory. We will compare it against an alternative to get a comparison of how well it does. This alternative is a simple *cyclic model* that is a good match with the cosmological data, and a realistic physical model.

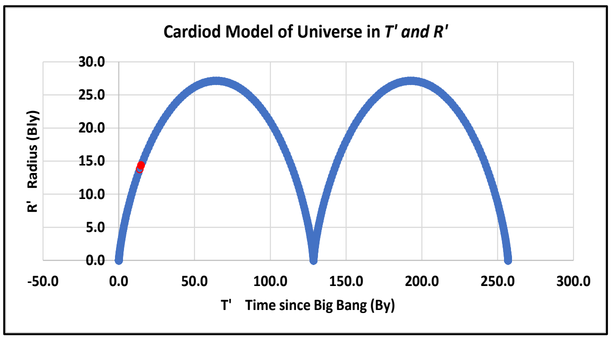


Figure 2. The Cardioid cosmology. This is a cyclic model with a completely different shape to the standard model. It is much simpler, but it matches the empirical data surprisingly well.

$$R' = R'_{MAX} \sin^2(A'T') \text{ with: } A' = (\pi/2T'_{MAX}).$$

Note it does not contract to a singularity but bounces at a small radius, and the cycle repeats.

Now there could hardly be two more strikingly different pictures of cosmology! We will see the short-term predictions are similar, but the long-term behaviour is completely different.

- Is such an alternative model viable? Is a cyclic cosmology still a realistic possibility?
- Haven't such models been ruled out by the standard model and discovery of dark energy?

- Could two such different cosmological models both still be plausible?

Physicists may immediately say it is impossible. But how do they know? Because they believe in General Relativity as an absolute true and perfect theory. An alternative to the standard cosmology cannot be correct if it differs from GR. “Not worth checking” say the physicists. But we checked to make sure.

The first main result is that the Cardioid expansion curve fits the observed data very well, giving very similar curves for red shift or Hubble parameter measurements against Age. This has been known for some time for the later universe (>2 By), but the curve is quite flat and it is hard to tell if it is just an accident. But now the very early-universe JWST data has also been found to match. Because the curves become quite steep in this region, this represents a strong match and strong confirmation.

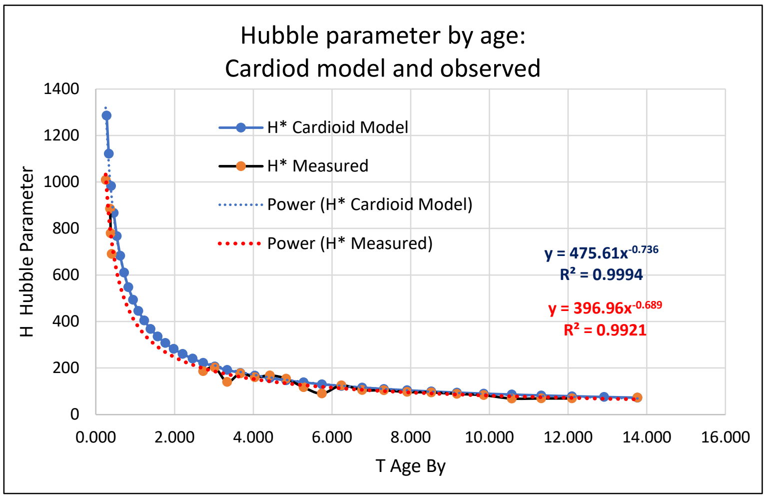
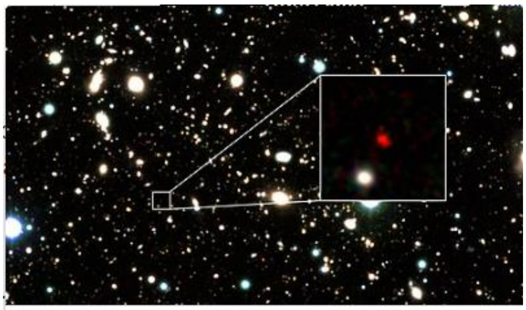


Figure 3. Matches of cardioid model and observed data, from 300 My – 14 By. We have put these results in terms of the *Age-Hubble match,* there is a similar data on red shifts. The data for this is given later.

The Cardioid model appears just as accurate as the standard model in the normal realm of observations. The next question is whether it can explain the recent JWST results. These are incomprehensible in the standard model, but the new model makes quite different predictions for the early universe.

Figure 4. Early galaxies detected by JWST. WIKIPEDIA.



HD1 is a proposed high-redshift galaxy, and is considered, as of April 2022, to be one of the earliest and most distant known galaxies yet identified in the observable universe. The galaxy, with an estimated redshift of approximately z = 13.27, is seen as it was about 324 million years after the Big Ba

These observations pose a direct existential threat to the standard theory of cosmology, and gravity. Until this new there has been a slow crisis, but scientists have been able to keep finding ways of patching up the standard model, by adjusting parameters. There have always been anomalies, such as the Hubble tension, the 10% difference in the Hubble constant measured by two different methods. Cosmologists have been able to ignore these and assume there will be a routine explanation within GR and the standard model. But the new JWST observations are too extreme to ignore.

The physicists’ process has been to fit their model to data <u>*without ever questioning the fundamental theory*</u>. *The form of their equations* is pre-determined by a general theory (GR or FLRW). There is freedom to adjust model parameters to match data, and this is done by assuming all relationships are fixed by the general theory.

This should have raised a concern that the standard model is built on *a single point of theoretical extrapolation*. GR has been extrapolated from the ordinary domains of gravity to the extreme domains of the early universe. Because data is scarce in these extreme domains, there has been much theorising, and little testing. But as the data has improved in leaps, this has *not* led to confirmation of the standard model, despite intense efforts by the scientists _to prove their theory right_. Data is first curated in *post-hoc* data modelling, to find the best match to *confirm the standard model*, but now it is increasingly contradictory.

The Cardioid model illustrates that practically the simplest possible cyclic solution, a sin-squared curve, matches the standard model almost exactly, with all its complexity and assumptions. This alternative function has the same behaviour in the main sequence we can observe, but it has a *completely different fundamental behaviour* at earlier and later times.

- It has only two parameters.
- It produces a quite different shape to the conventional expansion in the long term.
- It fits the observational data and standard model perfectly in the present term.

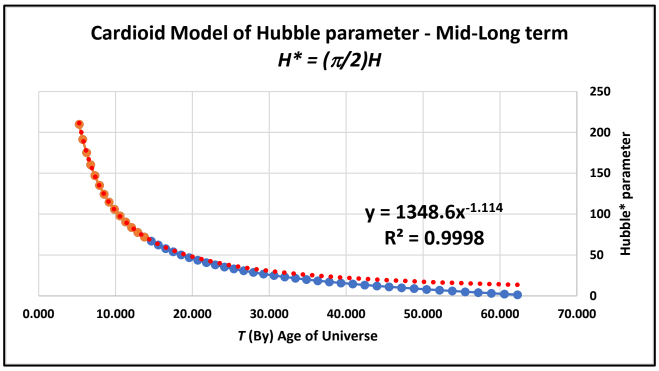


Figure 5. The Cardioid model predicts the blue line for the *long term expansion rate: it will go to zero, with expansion reaching a maximum at about 64 BY, and then contraction will start*. The standard model interprets an *acceleration term,* illustrated by the red dotted line.

If the blue curve represents actual expansion, the sub-set of data from *5 By to the present 13.8 By* will fit a power function which matches the conventional model in this period. But the long-term predictions diverge.

The differences may look small for most of this period, but after this *the cyclic H goes negative, and the universe contracts,* while the red line always remains positive, and the universe always expands. Indeed, they are radically different universes.

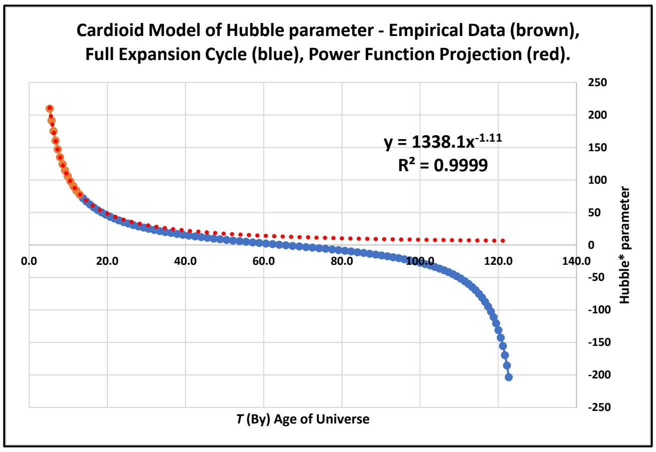


Figure 6. Predictions over a whole expansion cycle diverge. One or other theory *must be completely wrong*, but do we know which? Our prediction of the future relies entirely on being correct in our assumption that we have the correct underlying theory. Note the curves in the future are _strictly under-determined by the present data_ (brown), which is limited to before 13.8 By. If the choice of underlying model is wrong, then it *has no predictive power in the long-term.*

Hence the prediction of the long-term future *is not decided by the empirical data at all,* it depends on assuming the underlying model. This is what determines the general *shape of the curves.*

- The red curve above was created as a trend-line using the data from the Cardioid curve up to 13.8 By.
- Choosing a *power function* as the form of the underlying physical relationship *pre-determines the shape of the future long-term prediction,* whatever the present data is.
- If we suppose the real data actually conforms to the Cardioid model, we would nonetheless predict the (red) accelerating expansion _on the basis of the standard model_, and claim it has an excellent fit.
- The limited empirical data from the early universe is too weak to empirically determine the functions for the long-term future.

So current predictions of long-term behaviour are ***primarily determined by a priori assumptions*** of the fundamental theory, and the Cardioid model has a different theory to the standard model.

Cardioid model function. We just briefly state the Cardioid model function so we can see how simple it is. The *model* predicts the radius of the universe expanding over time, which we write as: $R(T)$ in conventional variables or: $R'(T')$ in model variables. Other properties like the Hubble parameter follow from the expansion function. The *Cardioid solution* is simply defined in model variables:

- $R' = R'_{MAX} \sin^2(\pi T'/2T'_{MAX})$ Cardioid model function.
- Defining: $A' = (\pi/2T'_{MAX})$ we write it as: $R' = R'_{MAX} \sin^2(A'T')$.
- Defining: $a'(A'T') = R'/R_0'$, we write it as: $R' = a'R_0'$.
- R'_{MAX} is the *maximum radius,* and T'_{MAX} is the time to maximum expansion.
- R'_0 *and* T'_0 are present values.
- $a'(T') = R'/R_0'$ is the *scale function* in model variables.
- $a(T) = R/R_0$ is the *scale function* in conventional variables.

Note: T'_{MAX} is half a full cycle, from zero radius to maximal radius. $\sin^2(A'T') = \sin^2(\theta)$ has period in θ of π not 2π. Note the Cardioid is classically written as: $R'(t) = 2a(1-\cos(\phi))$, with twice the angular variable: $\phi = 2\theta$.

This is about as simple as a model could be! It is much simpler than the standard model. It means *the expansion of the universe is pre-determined, and independent of processes inside the universe*! It does not have "dark energy" any other substances added to correct or parametrise the solution.

It may first be taken as simply a postulate that *there is a characteristic cyclic function for expansion,* much like the elliptical paths of planets, and it can be tested in the first instance as simply an empirical model.

But it is not written in the normal *measurement variables,* and the key point is that there are *variable transformations* that must be made, to go from the Cardioid model variables (dashed) to standard measurement variables (undashed), to relate it to observations. The Cardioid solution in fact comes from a theory which unifies gravity with quantum particle physics, and this determines the solution. This is its first evidence. But the cosmological predictions are quite simple and definite by themselves, and their accuracy is a key reason to consider the theory seriously.

We will only look at the recent cosmological data here, and the reader is referred to earlier studies for more details of the full theory, and various other tests. We complete a quick overview of the main concepts in the rest of this introduction, then we go on to present results primarily in graphs of model comparisons. We refer most details of the model equations to the Appendices. The theory has been developed in more detail in some other preprints (see References section). We provide the essential background here to specifically understand the cosmological model we propose.

We do not try prove it here, we just propose it as an alternative for the *expansion cycle,* to compare with the standard model, to see how *robust* the standard model is to a theory change. We find that key aspects of the standard model are not robust *against counterfactual theory change*.

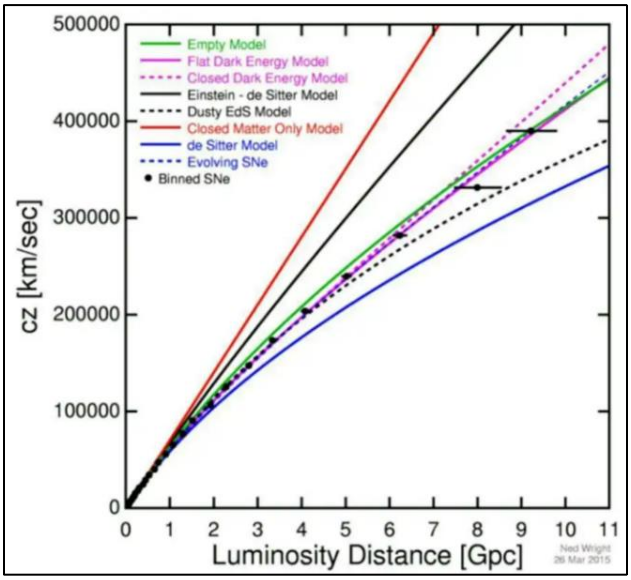
Aspects of the standard cosmology that are not robust in the new theory. *Dark energy disappears! The cosmological constant disappears! The universe has no singularity at the start! And it contracts in the future! Galaxies and stars form much faster! The early universe is filled with myriads of stars and galaxies! Local QM constants and global parameters are connected! The strength of gravity changes relative to the EM force!*

In terms of the alternative model, the main purpose here is to identify its matches with the new data and observational results, and provide results useful for others who may wish to investigate it further.

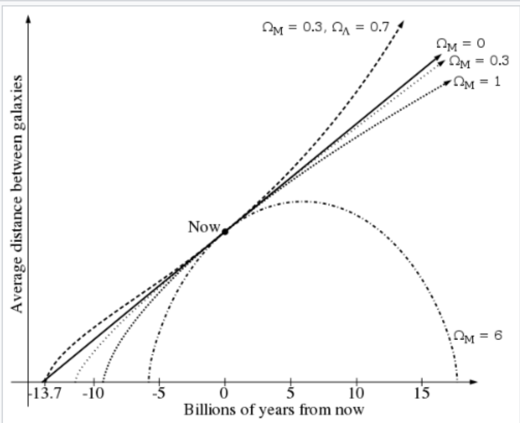
The Standard Model versus the Cardioid model.

In the standard model, mass-energy components are divided into different types (ΛCDM), and the mathematical form for these gives them different kinds of effects on the expansion.

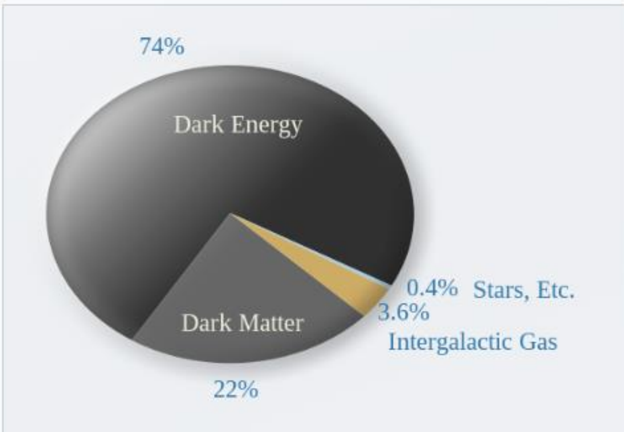
Figure 7. (Ned Wright, 2015) Variations of conventional GR models make different predictions for expansion, by mixing up different mass-energy types. In the *conventional model comparisons* illustrated here, the *dark energy model* conforms to the empirical data more closely than other models. This is its main evidence. It is the reason physicists now claim that *DE has been conclusively proven to make up 70% of the universe!*



The standard model cannot work without dark matter and dark energy and the cosmological constant. The big theme in modern cosmology for two decades has been to establish *the proportions of types of exotic matter* required for the standard model to work.



The age and ultimate fate of the universe can be determined by measuring the Hubble constant today and extrapolating with the observed value of the deceleration parameter, uniquely characterized by values of density parameters (Ω_M for matter and Ω_Λ for dark energy). A "closed universe" with $\Omega_M > 1$ and $\Omega_\Lambda = 0$ comes to an end in a Big Crunch and is considerably younger than its Hubble age. An "open universe" with $\Omega_M \leq 1$ and $\Omega_\Lambda = 0$ expands forever and has an age that is closer to its Hubble age. For the accelerating universe with nonzero Ω_Λ that we inhabit, the age of the universe is coincidentally very close to the Hubble age.



Estimated relative distribution for components of the energy density of the universe. Dark energy dominates the total energy (74%) while dark matter (22%) constitutes most of the mass. Of the remaining baryonic matter (4%), only one tenth is compact. In February 2015, the European-led research team behind the Planck cosmology probe released new data refining these values to 4.9% ordinary matter, 25.9% dark matter and 69.1% dark energy.

Figure 8. WIKIPEDIA. The fate of the universe and the proportion of dark energy in the universe. Estimates vary substantially, from about 68%-74%. Note that dark matter is independently real, inferred from gravitational phenomenon. But dark energy is a purely theoretical substance *to keep the standard cosmology alive*. It is purely to explain the Hubble acceleration.

This detail makes the standard cosmology complicated. But we do not have this complexity in the Cardioid model, it is very simple and deterministic. However, there is something critical that we must get right, transformations between the model variables and conventional measurement variables.

The Cardioid Variable Transformations.

The main point is that we need to *counterfactually compare two different fundamental theories with each other*. These theories have *incompatible laws.* They are written in two different systems of variables.

- The (dashed) variables, *R', T'* are our Cardioid model variables, and must be transformed into conventional variables, *R* and *T*, to relate to our normal physical measurements.
- The alternative model is written in these "true" *space-time variables, R', T',* which are related to our conventional variables, *R, T,* by a set of transformations determined by their instrumental definitions.
- The general equations of the new theory are simple in the true model variables. But in conventional variables they are messy and lack time invariance.

The dramatic possibility of transforming to a new variable system has been overlooked in modern cosmology.

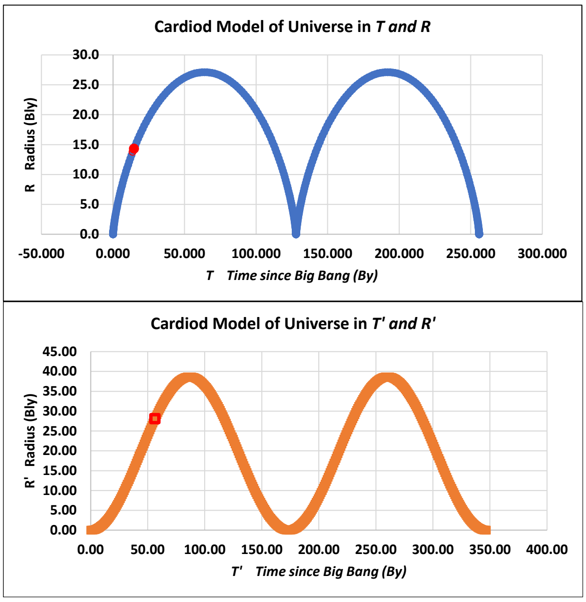


Figure 9. Universe expansion on Cardioid model, seen in two different variable systems. Smooth evolution of variables in *(R',T')* becomes distorted in *(R,T).* The *present time* is indicated by the red markers. In *T'* we are 2/3's through the universe expansion phase, but in *T* we are only 1/3.

Physicists spend lots of time making *coordinate transformations*, within the theoretical frameworks of the theories we are working in. E.g. the Lorentz transformations are the transformations in SR. These are generalized in the relativistic tensor calculus.

But while these are valid coordinate transformations within a theory, because they preserve the laws of the theory, *they do not transform variables between theories, e.g. the LT's do not relate classical physics to relativistic physics*. They are not *inter-theoretic translations of variables.*

What we are showing in this diagram is an *alternative model, simulated in its own variables (bottom),* then transformed into the *standard theory variables (top),* which is what it will look like to us normally. But note *the new process seen in the standard variables will no longer be consistent with our standard theory.*

To appreciate this, suppose we are back in the 1900's, and physicists have made a whole lot of measurements, on the basis of classical physics. They provide us with tables of astronomical data, recorded in the usual classical variables *r, t.* But we wish to propose a new theory, *special relativity*, which has variables: *r', t'* and laws that are not compatible with CM. We require a *new analysis of measurement in our new theory* to relate the theories. The measurement data does not change, but we need to *transform the classical data variables (interpreted from raw data via classical assumptions), into the variables of our new theory.*

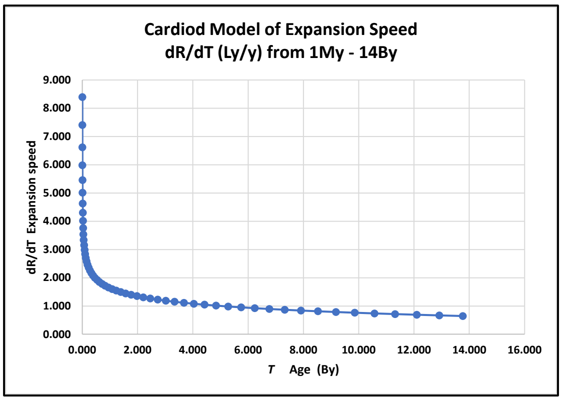
- These inter-theoretic translations are not the Lorentz transformations, or coordinate transformation within either theory.
- They ultimately reflect *models of the physical measurement processes,* which fixes how the new theory predicts measured quantities in *r, t*.
- In our theory, they are expressed as general coordinate transformations, which are consistent with standard models of QM without gravity, but are different when gravity is involved.

The effect is seen by comparing expansion speeds in the two variable systems.

Cardioid model of expansion speed in conventional and model time variable.

These are images of the same process in different time variables!

Figure 10. Expansion speed. Cardioid expansion in conventional variables begins explosively and is decreasing quite linearly in the recent era, from about 2 By to the present 14 By. The earlier we go back the more explosive the expansion is, if we go back early enough it is like the "inflationary" period in the first microseconds of the standard model.

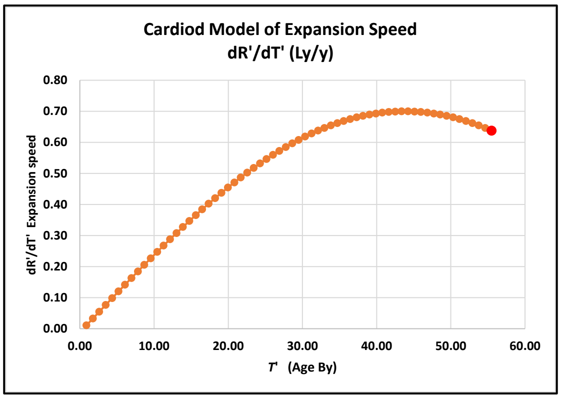


The standard model starts from a "Big Bang" singularity. But in the Cardioid model there is a minimum radius, of about 10^4 Km. The universe did not appear from an infinitely explosive process from a "singularity" of infinite density. Nonetheless it appears to be violently explosive, back to the first few seconds.

How can this *violently explosive process* be the same reality as the *gentle cyclic process* below?

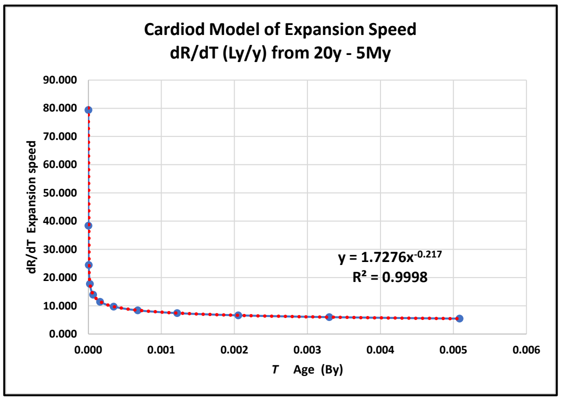
Figure 11. Right. Expansion speed in the model variables is a smooth cyclic process, and completely different to the graph in conventional variables above. But they are the same process. Note the *present age* in model variables is about 56 By.

The expansion starts slowly in: *dR'/dT'*, but when transformed into: *dR/dT*, it appears as the explosive expansion. It is a smooth cyclic curve, and the appearance of explosion is an illusion from the variable transformations.



The expansion speed: *dR'/dT'* increases until half-way through the expansion cycle ($A'T' = \pi/4$), and then it decreases. This half-way point in the cycle is about 5 By in normal time, and 43 By in model time. This is the period of observations that forced cosmologists to introduce "dark energy" and the cosmological constant, giving the current Λ*CDM* model. These observations give changes in the Hubble parameter, which represents the speed of expansion. In the standard model this corresponds to fitting a *power function,* as the mathematical form forced by the FLRW model. We see this fits the short-term data well! But in fact, this data is far too weak to determine what the underlying relationship is.

Figure 12. Expansion speed before 5 M years. This closely matches a power function. It is increasingly explosive the earlier we go. This graph starts when the universe was about 20 years old.



Note expansion rate cannot be measured directly, and the main data for testing the models are derived measurements, such as the Hubble constant, estimated from red-shift and distance data. But it is essential to appreciate that we must calculate predictions for the new model as a counterfactual theory.

Counterfactual theory testing.

We emphasise we are *testing the standard model or theory against an alternative model.* We do this by simulating the new model, then translating the outcomes into conventional measurement variables, so we can see how they match the data. Note we do *not* start from the standard theory and try to work out the results of the new theory in the standard variables! That won't make any sense. We must test *counterfactually.*

This is analogous to the process Einstein worked though in his famous (1905) paper, where he defined Special Relativity as an *alternative to the classical theory,* with its own intrinsic system of variables for space and time. We see from that analogy that we are talking about *inter-theoretic translations,* not simply *coordinate transformations within a theory,* which is what physicists are familiar with.

- We are testing a *theory change*, not a *model choice* within a theory.

Some laws of a new theory (e.g. time dilation in SR) will *contradict corresponding laws of the old theory* (no time dilation in CM). They contradict each other when they are translated into the same variables, e.g.: $d\tau/dt = 1$ in CM*, versus:* $d\tau/dt = 1/\gamma$ in SR. That is the point: to compare a theory with an alternative theory *that has different laws*.

For ordinary physicists working in a theoretical framework, like classical physics or special relativity, a new theory often seems paradoxical or absurd. Many classical physicists had difficulty comprehending special relativity. Physicists assume a class of *valid coordinate transformations* as the backbone of their theories, and take them as inviolable definitions. But if we want to entertain an alternative theory which is *inconsistent with the standard theory*, we have to expect conflicts. We cannot take the standard theory as definitive of the concepts or definitions, and *we have to translate between variables of two theories* to compare them. We will define these translations with *differential functions*, but they have a different logic to normal coordinate transformations within a theory.

Because of the challenge of getting these transformations right, we need to make numerical simulations and carefully test results before we can have confidence. Doing this gives us two independent ways to confirm results. We illustrate a *numeric model simulation* in a spreadsheet, which look like this.

B7 =PI()*D5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	CARDIOID MODEL TAU COSMOLOGY						Empirical Age To	Empirical Radius Ro		Empirical expansion		Empirical Hubble Ho	Numeric errors	
2	©ATASA RESEARCH 2022.			Yellow-red cells set parameters.			13.80	13.77		67-73 (km/sec)/MPSec?		71.00		
3	TIME STEPS	TRUE VARIABLES: Dashed *T', R', H'*.					CONVENTIONAL VARIABLES.				Hubble conversion	1.02E-12	Time Flow Rate	
4	Empirical NOW=(1-100)	To' | T'MAX (By)	A'To' (Radian)	Ro' | R'MAX (Bly)	dRo'/dT' (Ly/y)	Ho' (1/By)	To | TMAX (By)	Ro|RMAX (Bly)	dR/dT speed (Ly/y)	Ho (1/By)	Hubble ((km/s)/MPS)	Ho π/2 ((km/s)/MPS)	Apparent age by true age.	Rate of Time flow.
5	64	55.493	1.005	27.546	0.638	0.023	13.76	13.77	0.644	0.047	45.9	72.0	0.248	0.980
6	0.867	86.71	1.571	38.64	0.01	0.000	63.98	27.10	0.0	0.0	0.3	0.4	0.74	1.97
7	TMAX' = πRo'	86.5	RMAX = Vo^2Ro	38.757	TMAX = 3π/8 RMAX^2/Ro		63.855			TRUE	TRUE	MEASURED		2% error numeric
8	T' increments 0 - 100	T' = true time Byrs.	A'T' = (π/2) (T'/T'max)	R' = R'max sin^2(A'T')	dR'/dT' Numeric	H' = (dR'/dT') / R'	T = f(T') = conventional time Byrs.	R = R'^2/2Ro'	dR/dT (ly/y)	H = (dR/dT) /R (1/By)	H ((km/sec)/MParSec)	πH/2	T/T'	dT/dT'
58	49	42.49	0.77	18.71	0.70	0.04	4.423	6.4	1.046	0.165	161	253	0.104	0.447
59	**50**	**43.35**	0.79	**19.32**	0.70	**0.04**	**4.836**	**6.8**	1.014	0.150	147	230	**0.112**	0.477
60	51	44.22	0.80	19.93	0.70	0.04	5.276	7.2	0.982	0.136	134	210	0.119	0.508
61	52	45.09	0.82	20.53	0.70	0.03	5.744	7.7	0.952	0.124	122	192	0.127	0.539
62	53	45.96	0.83	21.14	0.70	0.03	6.240	8.1	0.922	0.114	112	175	0.136	0.572
63	54	46.82	0.85	21.74	0.70	0.03	6.765	8.6	0.894	0.104	102	160	0.144	0.606
64	55	47.69	0.86	22.34	0.69	0.03	7.320	9.1	0.866	0.096	94	147	0.154	0.640
65	56	48.56	0.88	22.94	0.69	0.03	7.906	9.6	0.839	0.088	86	135	0.163	0.676
66	57	49.42	0.90	23.53	0.69	0.03	8.523	10.1	0.812	0.081	79	124	0.172	0.712
67	58	50.29	0.91	24.12	0.68	0.03	9.172	10.6	0.787	0.074	73	115	0.182	0.748
68	59	51.16	0.93	24.71	0.68	0.03	9.854	11.1	0.762	0.069	67	106	0.193	0.786
69	60	52.02	0.94	25.29	0.67	0.03	10.568	11.6	0.737	0.063	62	98	0.203	0.824
70	61	52.89	0.96	25.86	0.66	0.03	11.316	12.1	0.713	0.059	58	90	0.214	0.862
71	62	53.76	0.97	26.43	0.65	0.02	12.097	12.7	0.690	0.054	53	84	0.225	0.901
72	63	54.63	0.99	26.99	0.65	0.02	12.912	13.2	0.667	0.050	49	78	0.236	0.940
73	**64**	**55.49**	1.01	**27.55**	0.64	**0.02**	13.762	13.8	0.644	0.047	46	72	**0.248**	0.980

Figure 13. Spreadsheet simulating the Cardioid universe in 100 time steps, with transformations of *T',R',H'* variables to *T, R, H.* We calculate functions both numerically and analytically and compare results, and check solutions match. We can model the whole cosmology quite accurately in a simple spreadsheet.

We can provide a copy of this spreadsheet, see Appendix.

Witze six key anomalies from JWST.

We now summarise key points of difference between the models, focussing on the anomalies appearing in the new JWST data. A good early survey article is Alexandra Witze 2022, *"Four revelations from the Webb telescope about distant galaxies."* 27 July 2022. Nature 608, 18-19 (2022). This surveys early JWST data studies, and we note six key points of interest for comparison with the Cardioid model.

Alexandra Witze 2022 commentary and quotes.

A. Early formation of stars and galaxies in the early Universe.

"Combined with 11 previously known galaxies, the findings show that there was a significant population of galaxies forming stars in the early Universe[1]. Perhaps the highest-profile rush is the stampede of research teams vying to … break Hubble's record for the most-distant galaxy, which dates to around 400 million years after the Big Bang[2,3]. One contender popped up in a Webb survey called GLASS that included another, slightly less faraway galaxy in the same image[4]. "

> "The fact that we found these two bright galaxies, that was really a surprise," says Marco Castellano, an astronomer at the National Institute for Astrophysics in Rome. He and his colleagues weren't expecting to find any galaxies that distant in this small part of the sky.

B. Multiple high-red-shift galaxies.

"A second team also independently spotted the two galaxies[5]. The GLASS candidate has a redshift of about 13. But on 25 and 26 July, days after astronomers reported the GLASS galaxies, papers claiming even higher redshifts flooded the arXiv preprint server. One candidate, at a redshift of 14, emerged in a survey called CEERS, one of Webb's highest-profile early projects. Another study looked at the very first deep-field image from Webb, released by US President Joe Biden on 11 July, and found two potential galaxies at a redshift of 16, which would place them just 250 million years after the Big Bang[7]. And arXiv papers speculate on other candidates, even out to redshifts of 20[8]."

C. Early galaxies shaped like disks.

"Webb's distant galaxies are also turning out to have more structure than astronomers had expected. One study of Webb's first deep-field image found a surprisingly large number of distant galaxies that are shaped like disks[9]. Webb observations suggest there are up to ten times as many distant disk-shaped galaxies as previously thought."

> "With the resolution of James Webb, we are able to see that galaxies have disks way earlier than we thought they did," says Allison Kirkpatrick, an astronomer at the University of Kansas in Lawrence. That's a problem, she says, because it contradicts earlier theories of galaxy evolution. "We're going to have to figure that out."

D. Early massive galaxies.

"Another preprint manuscript suggests that massive galaxies formed earlier in the Universe than previously known. A team led by Ivo Labbé at the Swinburne University of Technology in Melbourne, Australia, reports finding seven massive galaxies in the CEERS field, with redshifts between 7 and 10[10]."

> "We infer that the central regions of at least some massive galaxies were already largely in place 500 million years after the Big Bang, and that massive galaxy formation began extremely early in the history of the Universe," the scientists write.

E. Galactic chemistry different to expected.

"Studies of galactic chemistry also show a rich and complicated picture emerging from the Webb data. One analysis of the first deep-field image examined the light emitted by galaxies at a redshift of 5 or greater. It found a surprising richness of elements such as oxygen[11]."

> Astronomers had thought that the process of chemical enrichment — in which stars fuse hydrogen and helium to form heavier elements — took a while, but the finding that it is under way in early galaxies "will make us rethink the speed at which star formation occurs", Kirkpatrick says.

F. Closer galaxies are smaller than expected.

"One study looked at … the period approximately three billion years after the Big Bang. … At the infrared wavelengths detected by Webb, most of the massive galaxies looked much smaller than they did in Hubble images[12]."

> "It potentially changes our whole view of how galaxy sizes evolve over time," Suess says. Hubble studies suggested that galaxies start out small and grow bigger over time, but the Webb findings hint that Hubble didn't have the whole picture, and so galactic evolution might be more complicated than scientists had anticipated.

"References. (repeated in References.)
1. Donnan, C. T. et al. Preprint at https://arxiv.org/abs/2207.12356 (2022).
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3. Jiang, L. et al. Nature Astron. 5, 256–261 (2021).
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6. Finkelstein, S. L. et al. Preprint at https://arxiv.org/abs/2207.12474 (2022).
7. Atek, H. et al. Preprint at https://arxiv.org/abs/2207.12338 (2022).
8. Yan, H. et al. Preprint at https://arxiv.org/abs/2207.11558 (2022).
9. Ferreira, L. et al. Preprint at https://arxiv.org/abs/2207.09428 (2022).
10. Labbé, I. et al. Preprint at https://arxiv.org/abs/2207.12446 (2022).
11. Trump, J. R. et al. Preprint at https://arxiv.org/abs/2207.12388 (2022).
12. Suess, K. A. et al. Preprint at https://arxiv.org/abs/2207.10655 (2022)."

This group of anomalies is what got the science media excited in mid-2022, with pronouncements that the standard model is dead, and cosmology is in crisis with no reliable theory to guide it. Some have been arguing this for decades, but main-stream cosmologists have stuck to the standard model like glue. They have no other theory. But the new JWST data has brought home that the problems are *real*. It means the conflicts of theory and experiments can no longer be swept under the theoretical carpet. This makes it perhaps the most revolutionary moment since the discovery of the red shift data, that now signifies the Big Bang.

The Cardioid cosmology has a different fundamental theory. It was proposed in [Holster, 2014, 2015]. It does not introduce any speculation about new types of particles: *it entails the (cyclic) cosmology independently of particle mechanics.* It has been tested with other data but the new JWST observations provide stronger evidence in the key realm of early cosmology, where the theories diverge. We will go through the points above and see. In all cases it gives good qualitative and quantitative predictions. It predicts the whole group of anomalous phenomenon, primarily from one cause: the gravitational constant was larger in the early universe.

The other central empirical concept is the Hubble *parameter.* The *Hubble tension,* a discrepancy in the standard model predictions, has been a prominent issue for over ten years, and is unresolved. Separately, there is the anomaly in the Hubble parameter on normal models of matter, and *dark energy* had to be added, with the *lambda* term to keep the balance, to give the *lambda-cold-dark-matter* model: λ*CMD*. We briefly summarise this

Hubble parameter.

Primary empirical predictions of the Cardioid model are for the value and behaviour of the Hubble parameter over time. This is how we first match it to empirical cosmology. There are two main issues. One is about *dark energy.* The *Hubble acceleration data* (which is real) has led cosmologists to postulate *dark energy* to be consistent with the standard FLRW model. But in the Cardioid model this appears as purely theoretical speculation. There is no dark energy required to explain the evolution of the Hubble parameter. Dark energy is the result of extrapolating GR beyond its domain of validity. The second issue is the *Hubble tension,* an issue that has been prominent for ten years now. This type of anomaly is expected in the Cardioid model, although the precise interpretation may be debateable.

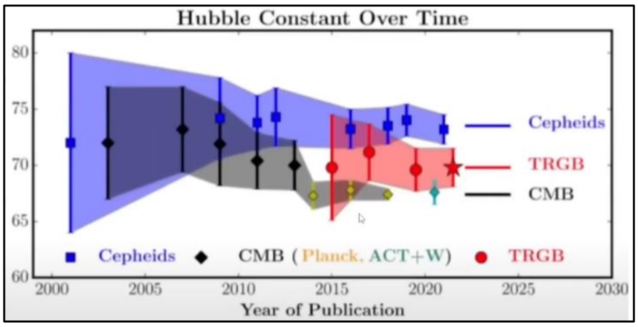

Figure 14. The Hubble tension. *H* measured by three different methods gives three significantly different results, around 67, 70 and 73 (m/s)/MPSecs. They differ by 10%.

[Physics needs to face its Demons – YouTube]

The biggest source of complexity and empirical uncertainty lies in measuring *distances* to distant galaxies accurately. We can work out *red shifts* quite well, from shifts in the wave-lengths or frequencies of known spectral lines. But we also need *primary distance measurements* to establish a time scale, and obtain the rate of expansion, which we want to map over time. The Hubble parameter is the (normalised) *rate of expansion*.

The *red shift* shows how much light has stretched, and hence how much space has stretched, since the light left the star. This tells us the *ratio* by which the universe has stretched (no matter what its total radius is) since the light left the source. But we also need to know how *long ago the light was produced,* to relate the stretching to time, and get a rate of expansion. To estimate this, we need *distances to the sources.* Because light travels at a constant speed, we can infer times from distances. Estimating *distances* is the only known way to establish times of cosmological events – except for the CMBR.

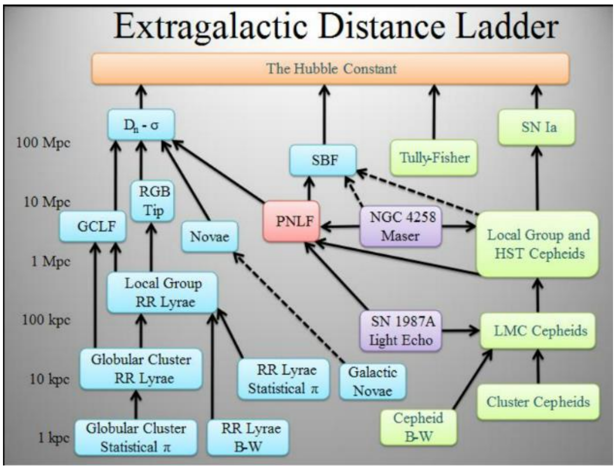

Figure 15. Luminosity-distance relation. "When distant stars at the TRGB are measured in the I-band (in the infrared), their luminosity is somewhat insensitive to their composition of elements heavier than helium (metallicity) or their mass; they are a standard candle with an I-band absolute magnitude of –4.0±0.1.[3] This makes the technique especially useful as a distance indicator." WKIPEDIA.

Because we have to transform between the measurements variables and our new variables, and we have to model the *measurement processes* in the new model and derive the predictions for the *conventional observations* (they will not generally be the same as the predictions of the standard model), this may appear to be fraught with a lot of complexity.

But we will see that for the most part, matching this with the new theory is fairly straightforward.

Cardioid equation and TAU metric.

Before going on to results, I briefly note the model equations correspond to a non-standard metric. This is summarised in Appendices, but it is important to emphasise the difference with standard cosmology.

The standard cosmology is based on the Friedmann metric, which is a solution for GR.

$c^2 d\tau^2 = c^2 dt^2 - a(t)^2 \mathbf{dr}^2$ *FLRW* metric for standard model.

where ***dr*** is the 3D space metric term (often written as $d\Sigma$). All *isotropic GR cosmologies* have this form. For modern cosmologists, this is *THE LAW OF COSMOLOGY,* and it is set in stone! What physicists call "alternative cosmologies" are variations in the term *a(t).* Why is this law set in stone? Because it is the only isotropic solution consistent with GR. It is General Relativity that is set in stone! The Cardioid model instead obeys:

$c^2 d\tau'^2 = c^2 dt'^2 a'(t')^2 - a'(t')^4 \mathbf{dr'}^2$ TAU metric for Cardioid model

Note this is written in a different variable system, and it translates into conventional variables as:

$c^2 d\tau^2 = c^2 dt^2/a(t) - a(t) dr^2$ TAU in conventional variables.

This requires: $c^2dt^2/a - adr^2 = a'^2c^2dt'^2 - a'^4dr'^2$, with: $dt = dt'a'^2$ *and:* $dr = dr'a'$ *and:* $a = a'^2$.

- These two metrics *cannot be transformed into each other,* and they are *inconsistent.*

We cannot make a second term in *a(t)* appear in the FLRW equation by transforming *a(t).* We cannot make one of the *a(t)* terms in the Cardioid equations disappear by transforming to another system of variables.

Also note the basis for dτ' changes: $d\tau' = d\tau_0/a'$, and inversely for space: $dr' = dr_0 a'$, so that: $d\tau' dr' = constant.$

But: $d\tau\, dr \neq constant.$ It is not *time translation invariant* in ordinary variables, but it is in the model variables.

- But how can this be consistent, if the FLRW is the only consistent isotropic solution in GR?

Well *it is not consistent with the FLRW or GR*. But it is a consistent model in its own terms. The full model is a unification of GR and QM in a six dimensional geometric space, and it is consistent in this space. This was found first, and the cosmology here worked out subsequently. It is not the only possibility, but it appears as the central solution to examine, like sine waves for EM radiation, and it is very simple. We do not need to go into any details of unification or types of particles and matter to analyse it.

- It means the expansion cycle is a pre-determined form, like the orbit of a planet around the sun.

The TAU metric contradicts GR, but as it has not been analysed, physicists cannot tell you whether it is a viable theory. It takes some work to compare the two theories. However, the intuitive plausibility revolves around the major physical effect. It was proposed in the 1930s, revived in the 1960s, rejected in the 1970s. This is that *the gravitational constant, G, weakens with time.*

- The Cardioid model implies that *the value of G get weaker relative to the EM force as the universe expands.* Gravity appears stronger in the early universe, and gravitational processes run faster.

This contradicts the standard model. Physicists claim that strong empirical limits have been set on the present rate of change of *G* by lunar laser ranging and cosmological studies. But these claim are based on lazy analysis. Physicist have spent millions of dollars on high-tech equipment but cannot do the analysis required to match measurement to theory. Proper treatment of the measurements shows the data is consistent with the Cardioid model. On the other hand, the increased strength of *G* in the early universe plays the striking role in explaining the JWST data, speeding up early galaxy formation and galaxy rotation by hundreds of times.

Spreadsheet model.

B7 =PI()*D5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	CARDIOID MODEL TAU COSMOLOGY						Empirical Age To	Empirical Radius Ro		Empirical expansion		Empirical Hubble Ho	Numeric errors	
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3	TIME STEPS	TRUE VARIABLES: Dashed *T', R', H'*.					CONVENTIONAL VARIABLES.				Hubble conversion	1.02E-12	Time Flow Rate	
4	Empirical NOW=(1-100)	To' | T'MAX (By)	A'To' (Radian)	Ro' | R'MAX (Bly)	dRo'/dT' (Ly/y)	Ho' (1/By)	To | TMAX (By)	Ro|RMAX (Bly)	dR/dT speed (Ly/y)	Ho (1/By)	Hubble ((km/s)/MPS)	Ho π/2 ((km/s)/MPS)	Apparent age by true age.	Rate of Time flow.
5	64	55.493	1.005	27.546	0.638	0.023	13.76	13.77	0.644	0.047	45.9	72.0	0.248	0.980
6	0.867	86.71	1.571	38.64	0.01	0.000	63.98	27.10	0.0	0.0	0.3	0.4	0.74	1.97
7	TMAX' = πRo'	86.5	RMAX = Vo^2Ro	38.757	TMAX = 3π/8 RMAX^2/Ro		63.855			TRUE	TRUE	MEASURED		2% error numeric
8	T' increments 0 - 100	T' = true time Byrs.	A'T' = (π/2) (T'/T'max)	R' = R'max sin^2(A'T')	dR'/dT' Numeric	H' = (dR'/dT') / R'	T = f(T') = conventional time Byrs.	R = R'^2/2Ro'	dR/dT (ly/y)	H = (dR/dT) /R (1/By)	H ((km/sec)/MParSec)	πH/2	T/T'	dT/dT'
58	49	42.49	0.77	18.71	0.70	0.04	4.423	6.4	1.046	0.165	161	253	0.104	0.447
59	**50**	**43.35**	0.79	**19.32**	0.70	**0.04**	**4.836**	**6.8**	1.014	0.150	147	230	**0.112**	0.477
60	51	44.22	0.80	19.93	0.70	0.04	5.276	7.2	0.982	0.136	134	210	0.119	0.508
61	52	45.09	0.82	20.53	0.70	0.03	5.744	7.7	0.952	0.124	122	192	0.127	0.539
62	53	45.96	0.83	21.14	0.70	0.03	6.240	8.1	0.922	0.114	112	175	0.136	0.572
63	54	46.82	0.85	21.74	0.70	0.03	6.765	8.6	0.894	0.104	102	160	0.144	0.606
64	55	47.69	0.86	22.34	0.69	0.03	7.320	9.1	0.866	0.096	94	147	0.154	0.640
65	56	48.56	0.88	22.94	0.69	0.03	7.906	9.6	0.839	0.088	86	135	0.163	0.676
66	57	49.42	0.90	23.53	0.69	0.03	8.523	10.1	0.812	0.081	79	124	0.172	0.712
67	58	50.29	0.91	24.12	0.68	0.03	9.172	10.6	0.787	0.074	73	115	0.182	0.748
68	59	51.16	0.93	24.71	0.68	0.03	9.854	11.1	0.762	0.069	67	106	0.193	0.786
69	60	52.02	0.94	25.29	0.67	0.03	10.568	11.6	0.737	0.063	62	98	0.203	0.824
70	61	52.89	0.96	25.86	0.66	0.03	11.316	12.1	0.713	0.059	58	90	0.214	0.862
71	62	53.76	0.97	26.43	0.65	0.02	12.097	12.7	0.690	0.054	53	84	0.225	0.901
72	63	54.63	0.99	26.99	0.65	0.02	12.912	13.2	0.667	0.050	49	78	0.236	0.940
73	**64**	**55.49**	1.01	**27.55**	0.64	**0.02**	13.762	13.8	0.644	0.047	46	72	**0.248**	0.980

Figure 16. Spreadsheet simulating the Cardioid expansion in 100 steps, with transformations of the model variables: *T',R',H'* to the conventional measured variables: *T, R, H.*

The model is *calculated in the model variables,* in the first few columns (A:F), and then *transformed into the measurement variables* (G:L). Further columns are used to calculate a variety of other quantities.

We define: $c_0 = 1$ *(Ly/y),* so we do not include it in calculations*.* Time is in *By* and distance in *Bly*.

The picture shows row *50* (halfway through the expansion cycle) to 64 (our model for our present position in the cycle). These correspond to the *model times (T') of 43.36 By and 55.49 By.* They correspond to the *conventional times (T) of 4.84 By and 13.76 By.* So this covers about the last 9 Bys *in conventional time*, and this period appears as about 2/3rd of the total age *in conventional time*. In model variables, the amount of time *T'* in this period is similar (11 By), but the universe is five times older!

This spreadsheet model is set by three parameters: *our present position in the cycle (64/100, A5),* the *empirical age (13.80, G2),* and *the maximal radius (38.6, D6).* But there are really only two independent parameters, as *the maximal radius* is not independent. We leave it as a free parameter in the sheet so we can see how it behaves with other values. The empirical age is determined (for our era) as about 13.8 By. Hence the only actual free parameter we can choose for the model is our *present position in time.* This determines *Hubble parameters and red-shifts*, the empirical data we have to compare.

- **Our present position in the expansion cycle** is the *single essential open choice* to determine the model. This is set in cell (A5), as *64* out of *100* time-steps in this model. It is *1.005* radians or *57 degrees* through the cycle.
- **The current empirical age** T_0 is measured as *13.8 By.* The model parameter T'_{MAX} is what directly drives the model, but: $T'_{MAX} = 2\pi T_0$ giving: $T'_{MAX} = 2\pi(13.8) = 86.71$.
- **The current empirical radius** R_0 is not directly measurable. It highly *model-dependant* in cosmology. In our model it is related to the measured age, T_0. Note in our model, R_0 is a *radius of curvature*, and the *physical distance around the universe* is: $2\pi R_0 = 86.7$ *Bly.*
- **The conventional** "radius of the universe" may be interpreted as: $\pi R_0 = 43.4$ *Bly.*
- Note we now set T'_{MAX} at twice the value in the earlier model [Holster, 2015], see Appendix. We explain the modelling more in Appendices.

Primary model match.

The *current age and time position in the expansion cycle* fixes the model. The primary empirical match is to get the present Hubble parameter. This empirical measure combines more basic measures of red shift and distance. There is no freedom to adjust the *(conventional) age* (13.8 By) (which is measured in several different ways and predicted to have this value in TAU).

Adjusting the *position in the time cycle* alters the Hubble parameter. This is the single main adjustable parameter. But the Hubble parameter alters quite slowly and linearly in the middle of the time cycle. E.g. it decreases from about *72* → *52* if we set the time back from *0.64* to *0.50*. (Which to us now appears as about *T = 4By).* The Hubble parameter does not vary greatly except in the very late or very early universe, which is not realistic for us (now). So there is limited scope to adjust the *time position in the cycle*,

The model must predict the Hubble parameter (or equivalent expansion function) accurately, and it is very definite in its predictions. There is little scope to adjust parameters. In fact there is only one parameter free to choose, (T'_0/T'_{MAX}). This changes the *apparent shape of the expansion curve, as we see it from our perspective in the present.* It appears to match when the *present time T' is set* at 64/100th of the first quarter of the whole cycle, or $0.64 \times \pi/2$ = 1.007 radians.

There is a difference of $\pi/2$, or more generally $\tan(\theta)$, between the directly predicted H_0 in the model and the empirical measured value.

- The present value of the Hubble parameter H_0, calculated in the model, with no adjustment for *measurement factors*, is too small by $\pi/2$.
- The value of the Hubble parameter H generally in the model generally is too small by $\tan(A'T')$.
- This is a necessary scaling factor to match the empirical measurements and predictions of the Hubble parameter in the standard model.
- It is expected some such factor is needed, e.g. to correct *distance estimates,* which should differ on the two models, due to different luminosities.

J	K	L	M	N
Empirical expansion		Empirical Hubble Ho	Numeric errors	
67-73 (km/sec)/MPSec?		71.00		
Hubble conversion		1.02E-12	Time Flow Rate	
Ho (1/By)	Hubble ((km/s)/MPS)	Ho π/2 ((km/s)/MPS)	Apparent age by true age.	Rate of Time flow.
0.047	45.9	72.0	0.248	0.980
0.0	0.3	0.4	0.74	1.97
TRUE	TRUE	MEASURED		2% error numeric
H = (dR/dT) /R (1/By)	H ((km/sec)/MParSec)	πH/2	T/T'	dT/dT'
0.150	147	230	0.112	0.477
0.136	134	210	0.119	0.508
0.124	122	192	0.127	0.539
0.114	112	175	0.136	0.572
0.104	102	160	0.144	0.606
0.096	94	147	0.154	0.640
0.088	86	135	0.163	0.676
0.081	79	124	0.172	0.712
0.074	73	115	0.182	0.748
0.069	67	106	0.193	0.786
0.063	62	98	0.203	0.824
0.059	58	90	0.214	0.862
0.054	53	84	0.225	0.901
0.050	49	78	0.236	0.940
0.047	46	72	0.248	0.980
0.043	43	67	0.260	1.020
0.040	40	62	0.272	1.060

Row 64:	Radians:
*A'T' = 0.64 * PI()/2*	1.005

Figure 17. Hubble parameter scale. We scale the Hubble parameter (L:L), interpreting: $H^* = H \tan(A'T')$ as the empirically measured value. This is accurate *at the present time, which in the model* is: $(64/100)(\pi/2) = 1.005$ *radians,* and gives: $H_0^* = \pi H_0/2$.

With this interpretation the predicted Hubble parameter matches observations and the standard model very well across the whole observed period of evolution, going back to the early observations made by the JWST at around 400 My.

We have yet to fully explain this factor, but it is likely to reflect the construction of: $H = (dR/dT)/R$, where measurements of R reflect present distance across space, while measures of dR/dT reflect *comoving distance*. A scaling function is required at this point to match the distance interpretation, without solving it analytically. We fix this scaling of: $H^* = H \tan(A'T')$ for empirical predictions and, the Hubble predictions are reported for this variable: H^*.

Results.

Results 1. Match of the expansion curve.

The primary evidence is the match of the expansion curves on the two models, and with observations now going back to around 300 My, and *H* around ten times its present values, they match over a wide range.

We summarise data from several studies, which are in turn summaries of multiple studies, and the data and matches is quite decisive.

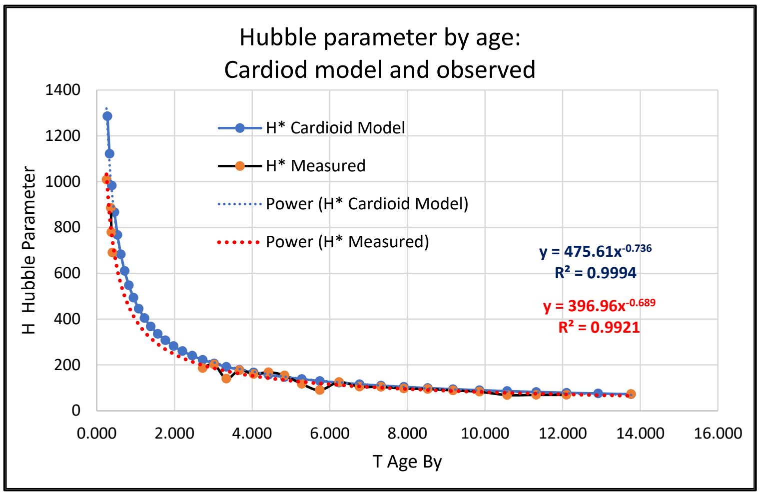


Figure 18. Cardioid model and standard model (multiple studies) match the Hubble parameter.

For the *power series trend-lines,* the intercepts are not important, note the exponential factors: $H = At^{-0.736}$, $H = At^{-0.689}$. The Hubble parameter combines several measurements, and observational studies use several methods. However, red shift is the primary observable that we can measure most directly, from the star-light.

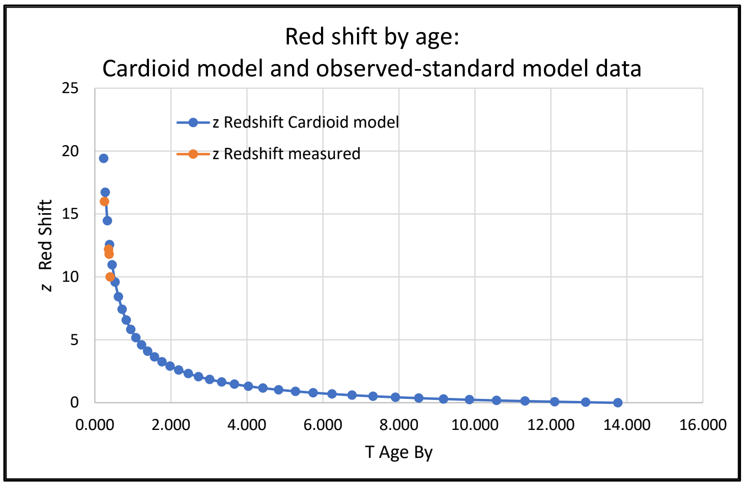


Figure 19. Red shift *z* by Age *T*. The results from around 3 BY – present match closely, as in the previous graph. This is new data from the early universe, and confirms the model match.

Tests 1. Finkelstein, Atek, et al. Early red-shift galaxies.

Comparison of four early red shift galaxies reported in 2022 with the Cardioid model.

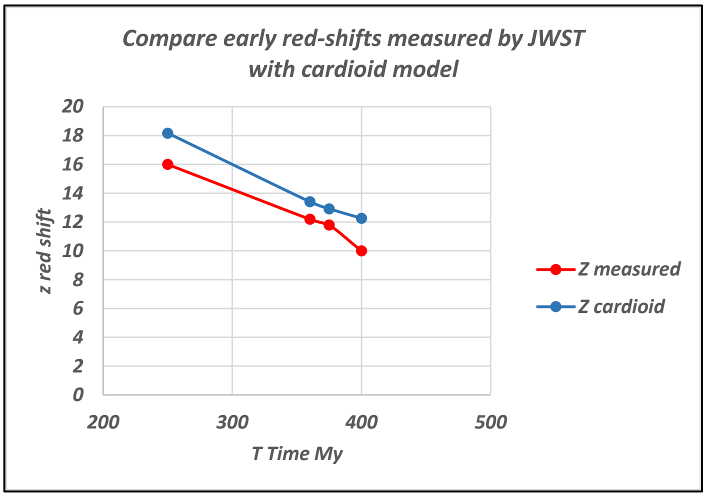


Figure 20. From the 12 references in Witze, three are on early high red shift galaxies. I found four data points for the earliest detected objects from two studies, Finkelstein 2022 and Atek 2022. The Cardioid model predicts that the times (age of universe) for these red shifts should be about 10%-20% larger.

Table 1. Red-shift by time samples from JWST data.

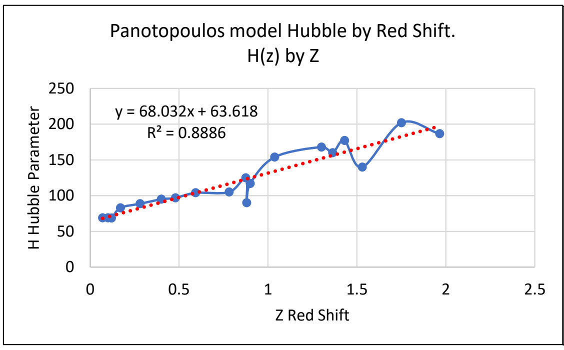
Type	Source	Z	T My	+ERROR	-ERROR
JWST Observational estimate	Finkelstein 2022	11.80	375	16	8
Cardiod Model	Predicted Z from T	12.92	375		
Cardiod Model	Predicted T from Z	11.78	410	Modelled /	1.09
JWST Observational estimate	Atek 2022	16.00	250		
Cardiod Model	Predicted Z from T	18.16	250		
Cardiod Model	Predicted T from Z	16.03	285	Modelled /	1.14
estimate	Atek 2022	12.20	360		
Cardiod Model	Predicted Z from T	13.41	360		
Cardiod Model	Predicted T from Z	12.10	400	Modelled /	1.11
JWST Observational estimate	Atek 2022	10.00	400		
Cardiod Model	Predicted Z from T	12.26	400		
Cardiod Model	Predicted T from Z	10.09	490	Modelled /	1.23

Each of these data points is close to the limits of observation records, and they are the result of extensive observation and analysis by the research teams. There is a lot of applied modelling already to extract the measurements from data. This models the role of ordinary matter like dust and stars in generating and filtering light, and the behaviour of photons, neutrinos, dark matter, and gravity waves. However, *dark energy* plays no role in the measurements. They are based measuring properties of light, like frequency, luminosity, period, polarisation. But dark energy does not interact with light or influence its path. And it was too small in the early universe (in the theory) to have much effect, until about 9By.

The Cardioid model predictions are close to these four new observations. The estimated red shifts are 10%-20% larger at these times, but this a good initial match, as the data has significant uncertainties. This confirms the viability of the Cardioid model.

Test 2. Panatopoulos. Middle red shift – Hubble parameter.

(Panotopolous *et al* 2019) was prior to the JWST observations, and report Hubble parameter measurements against red shifts with 18 data points up to red shifts of 2, and compare the Hubble evolution predicted on several models. They conclude the standard ΛCDM model is the best fit.



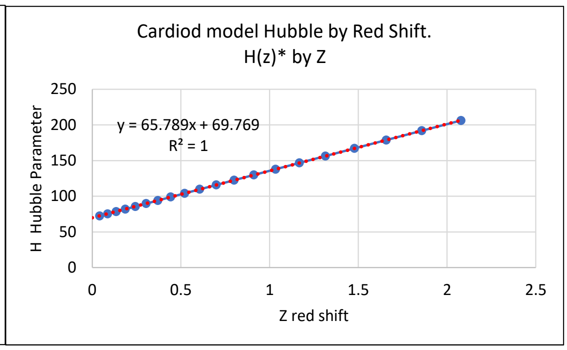
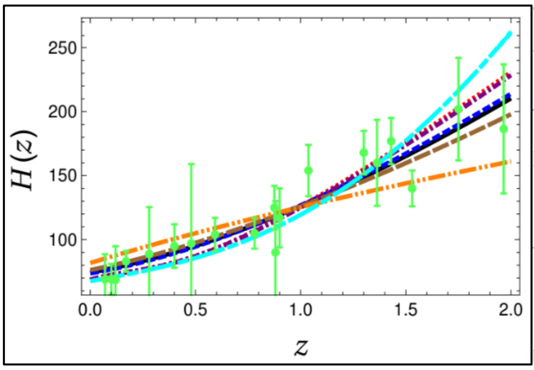


Figure 21. The data points are empirical observations, the interpretation is based on modelling assumptions which play some role, but altogether the values are quite robust. This has a good linear approximation, with a slope of about 68, which we compare with the Cardioid prediction below. (Intercepts are not important here.) **Figure 22.** The cardioid model has a linear approximation for the same section of data with a slope of about 66. This is consistent with the value of 68 from the empirical data and standard model above.

This seems quite a coincidence, but the Cardioid does not just match the data roughly, it matches the ΛCDM standard model quite specifically well, among several model variations tried in cosmology.

Panatopoulos, 2019. This shows seven models compared, with the data points indicated, 2019.



z Redshift Cardioid model	*H* Cardioid Model*
2.33	240
2.08	222
1.86	206
1.66	192
1.48	179
1.31	167
1.17	156
1.03	146.687
0.91	138
0.80	130
0.70	123
0.61	116
0.52	110
0.44	104
0.37	99
0.30	94
0.24	90
0.19	86
0.13	82
0.09	78
0.04	75
0	72

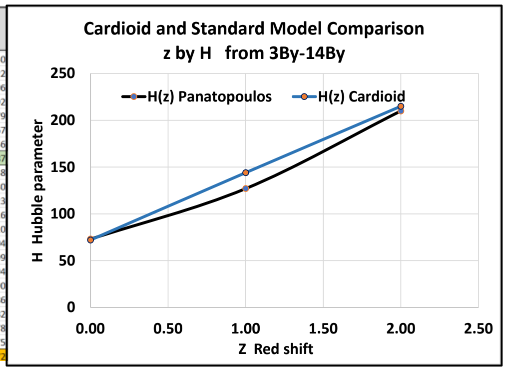


Figure 23. Left. "H as a function of red shift for seven models". Panatopoulos, 2019. These models have different combinations of matter, energy, etc. The main model (central black line) is the ΛCDM and conforms closest to the data. It also conforms most closely to the Cardioid model.

Figure 24. Right. Illustrating the relation between *z* and *H* for *z = 0 to z = 2* for *the standard model by Panatopoulas (2019),* and *the Cardioid model.* This *standard model* was fitted from about 27 data points, and it maximises the fit with the ΛCDM model. The cardioid model *is only fitted to match the present value of H (71)*.

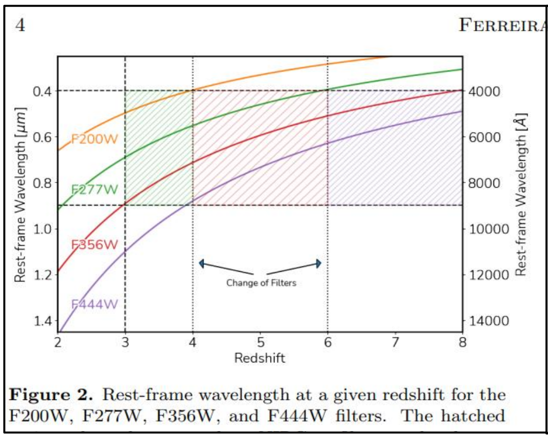
- These match within a few percent, back to about 2 By, and they match *closer than they match with the other standard models*.
- The Cardioid numerical model can be a few percent out, but more important, we have not discussed possible corrections in the measurement analysis, for distance or luminosity or mass.
- The empirical data has only 27 data points (each from another detailed study) to fix the standard model. This is small with quite large variance.

Considering the Cardioid model is just a simple cyclic function, with a simple shape*,* why does it match so well? The standard model took a vast amount of work to collect data and refine. It has taken years for the data to become accurate enough to fix the parameters, and there is still a lot of uncertainty. This is a truly remarkable achievement in experimental physics! But it appears we can predict it from our simple model.

This match with the *observed expansion process* is the first big test of the Cardioid model. To this point, there are only small differences between the theory and data, expected from natural variances in the data.

Test 3. Witze Ref 9. Ferreira Large red-shifts.

Ferreira *et al* (2022) relates red-shifts to rest-frame wave-lengths at large red-shifts.



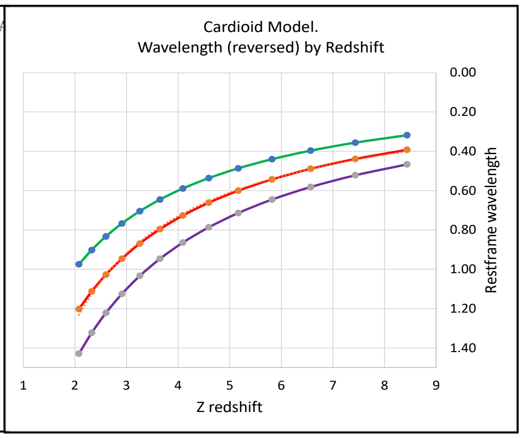


Figure 25. Ferreira *et al* 2022. Graph of red-shift to rest-frame wavelength. They are trying to establish robust empirical measurements for red-shifts in the early period. **Figure 26.** The Cardioid model is consistent with Ferreira (2022). It means our interpretation of variables and measurements matches. These are matching empirically, back to the very early observable universe*,* around 300 My*.*

Since our Cardioid model also matches the present time well (being set to get the present Hubble value right), it matches the whole standard model Hubble curve well, like *power-function trend lines* later.

Model 1. General.

Model. Expansion in different variables compared.

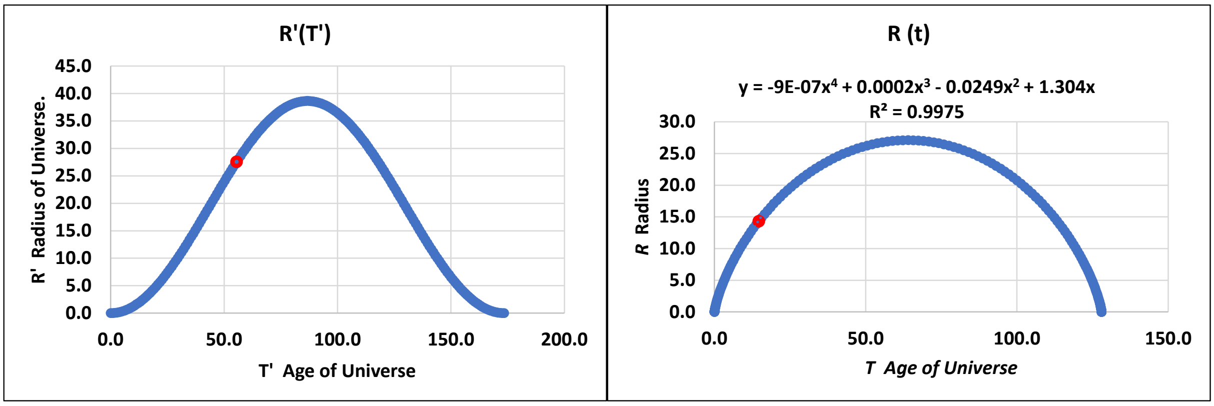


Figure 27. Two graphs of the Cardioid solution, in the two different variable systems. Left. In the *model variables*, *R'(T')* is a *sin-squared function*. Right. In conventional variables, *R(T)* is like an ellipse.

- See Appendix 1. Cardioid expansion function.
- Note that the *R(T) function* is really a complex trigonometric equation in *T,* but it is *modelled very closely* by a polynomial of order four, with *R-squared of 0.9975.*
- Models providing four or more polynomial factors are almost bound to get good matches.

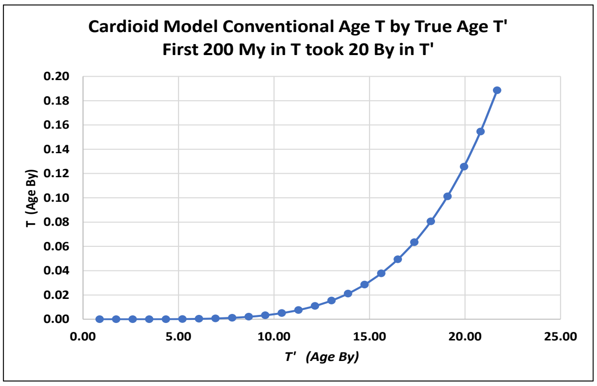


Figure 28. From around 100My - 200My in *T,* about 4 By pass in *T'.* This means 4 billion years of *gravitational processes* may occur in a period with only 100 million years of *QM or EM processes.*

This scaling of the time and space variables makes processes almost impossible to visualise without making graphs. We cannot trust our normal intuitions. We have to work out models as counterfactual propositions, and predict what the measurements will be.

The Hubble parameter also looks different in the different time variables.

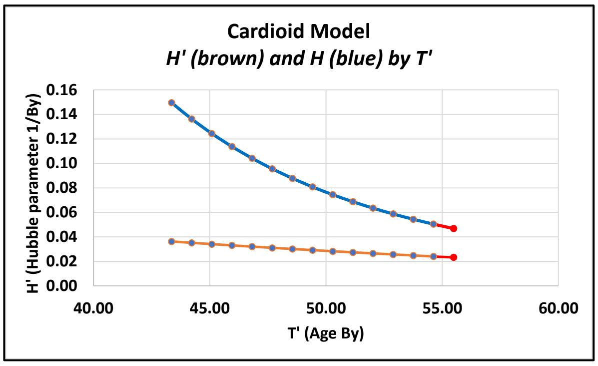
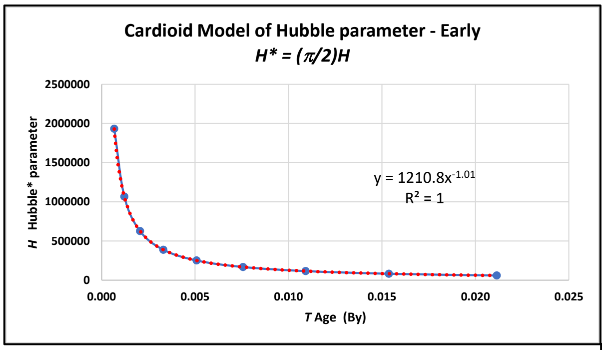


Figure 29. Relative behaviour of the Hubble parameter by time *T'* for *H* (top, blue) and *H'* (bottom, apricot). Time goes from about 5 By to 14 By in conventional time. These represent the same model of *H*, but in two different variable systems for time, because: *H* is equivalent to: *1/T.*

Model 1. *H* Early time.



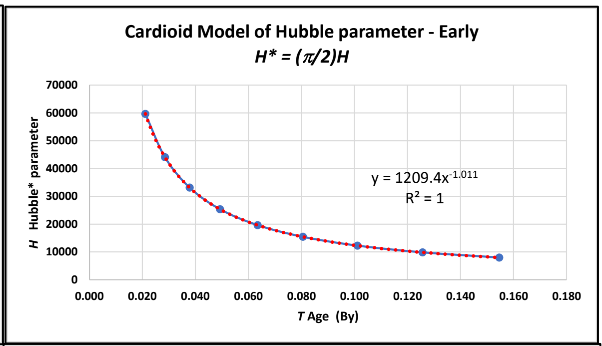
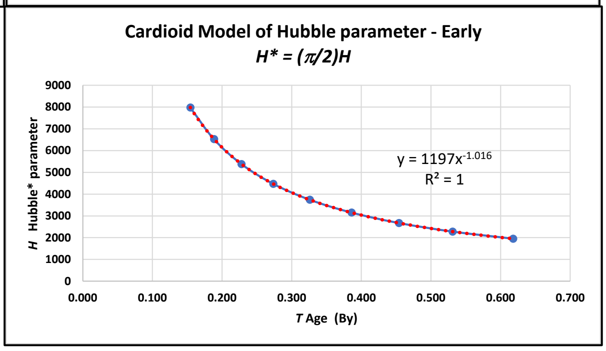


Figure 30. 1 – 20 My. Hubble parameter becomes astronomical as the radius shrinks.

Figure 31. 20My – 150 My. Just before the earliest galaxies observed with JWST.

Figure 32. The period around 300 – 600 My is where multiple disk galaxies and many very old galaxies have now been observed by JWST.



Notice how stable the parameters for the power function are, with $y \approx 1200\, x^{-1.01}$

Note if the two models have matching predictions of *red shifts* at early times, they also have matching predictions of *Hubble parameters*, since the *distance* is almost the same in both models, *c* times the age of the universe minus a small amount of time.

Model 2. Scale function over early-present time.

In our graphs, the cardioid is the blue curve, and the trendlines are the best fit to a power function. We can see how well they match the standard model for that part of the curve.

Figure 33. Friedmann Equation Solutions. WIKIPEDIA. The standard model tells us this power function of time, $a(t) = a_0 t^{2/3(w+1)}$, is the solution when it is spatially flat, meaning $k=0$.

Solutions with: *w=0 and w=1/3 correspond to matter* and *radiation.* Solutions with: *w →-1 have a cosmological constant, k not zero,* and do not necessarily conform to this power function.

- Note close to the present, this looks like the: $a(t) = a_0 t^{2/3(w+1)}$ solution with $w = 0$, and: $a(t) = a_0 t^{2/3}$. We have values of *0.664 and 0.633* around the 5 - 15 By period.
- This is like a standard model for a matter-dominated universe - but only for a limited period of time.

In spatially flat case ($k = 0$), the solution for the scale factor is

$$a(t) = a_0\, t^{\frac{2}{3(w+1)}}$$

$w = 0$ a matter-dominated universe

$$a(t) \propto t^{\frac{2}{3}} \text{ matter-dominated}$$

$w = \frac{1}{3}$ a radiation-dominated universe

$$a(t) \propto t^{\frac{1}{2}} \text{ radiation-dominated}$$

$w = -1$. In this case the energy density is constant and the scale factor grows exponentially. this solution is not valid for domination of the cosmological constant,

WIKIPEDIA **Friedmann Solution, Cosmology.**

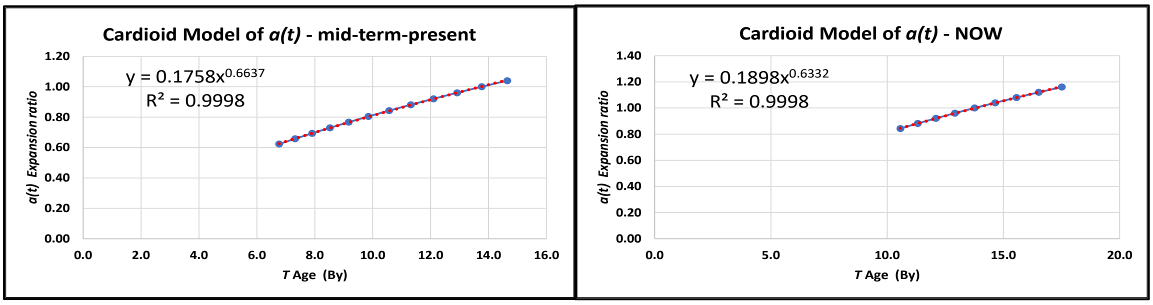


Figure 34. The power function matches in our short-term present, but not over a cycle.

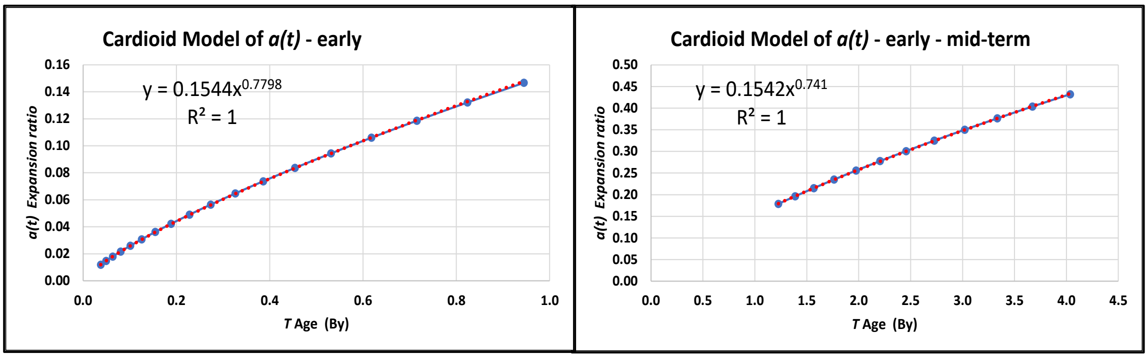


Figure 35. Earlier it still appears as a power function, with a slightly larger exponential.

The trend-line power function changes from: $t^{0.63}$ *to* $t^{0.67}$ *to* $t^{0.74}$ to $t^{0.78}$... It is not a power function, it is really the *sin-squared function*: $a(t)' = a_0 \sin^2(A'T')$. This is in the variable *t'*, not *t*, for time. And *a'* represents the radius ratio function: $a'(t') = R'(t')/R'_0$ for the spatial variable *r'*, not *r.*

Model 3. H over long time. 14 By – 120 By.

The Hubble parameter has the inverse behaviour.

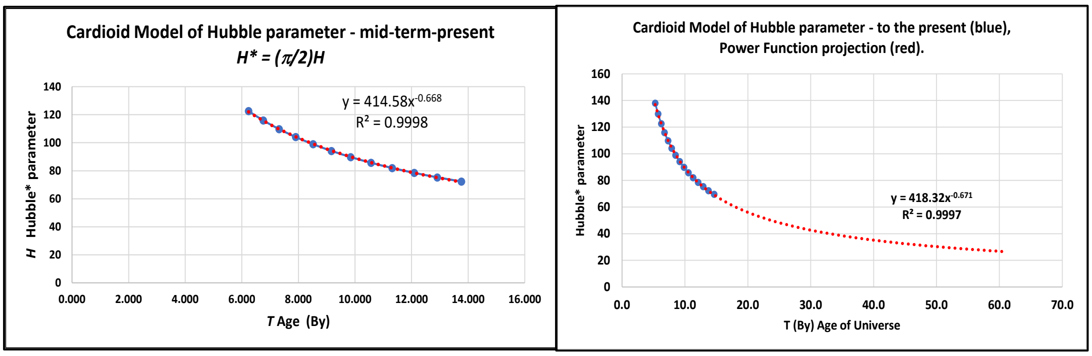


Figure 36. The power function matches in the short-term, but not over a cycle. Over a whole cycle, *H’* reduces to zero, and becomes negative.

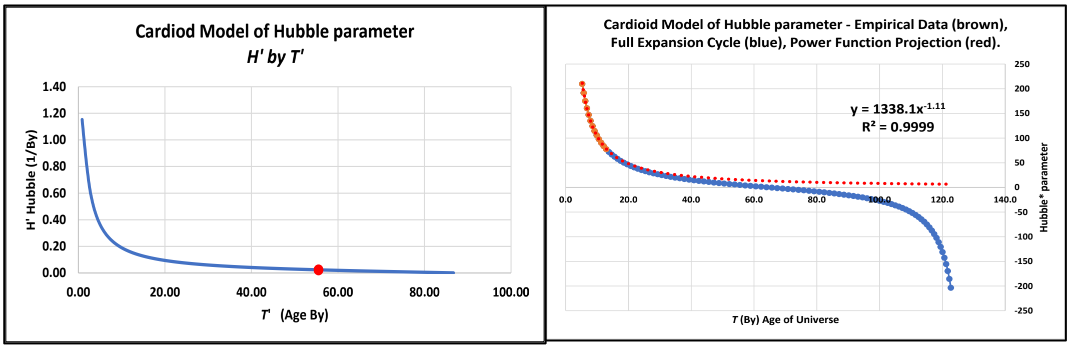


Figure 37. For the mid-term period a *power function* fits the data very well. But the data generating this curve is not a power function. The red point is the present in the true time variable. In the long-term, there is no match with the power function.

Results 2. Galaxy formation.

We have established direct matches between the model predictions for the expansion and the standard model fitted to observational data. Now what about the features of the new data, in the points *A-F* above?

On the Cardioid model:

- What are the expected formation rates of early stars and galaxies?
- Can we analyse luminosity? Sizes? Periods? Masses? Distances?
- Can we explain the Hubble tension?

Test 4. Rapid early galaxy and star formation in the early universe.

Figure 38. Castellano, M. et al. Preprint at https://arxiv.org/abs/2207.09436 (2022).

> What is most remarkable of this first search is that we have found two bright ($M_{UV} \lesssim$-21) sources, one at $z \sim 10$ and one at $z \sim 12$, well beyond the expectations based on the extrapolation of the LF at lower redshift. In fact, all observations and models predict a negligible number of sources brighter than this limit in the redshift range z=9-15 on an area equal to the GLASS one: the predictions being of $\lesssim$0.2 objects, compared to an observed number of $2^{+2.7}_{-1.4}$ (where the uncertainty includes both cosmic variance and the Poisson uncertainty for

Authors of this and other papers are startled to find ten times or more than the number of galaxies they expected in the early universe. At their first glance! Indeed, that is conservative: they are finding massive galaxies that appear impossible on the standard model.

They expected some early galaxies, on the basis of fuzzier HST data. But the standard model does not predict anything like this! It predicts much slower star and galaxy formation. Stars should only be appearing around 500 My ago, and galaxies should not form until about 1-2 By. It depends on the model. But slow rates of galaxy formation have been a problem for the standard model.

But this is the Cardioid model's big point of difference. It was previously its big *problem,* because its predictions for early gravity are different from the standard model. But now we find this is its strength. It predicts faster galaxy formation, and more dynamic early formation of large-scale structure.

- First it is expected to speed up gravitational collapse of dust clouds.
- Second it predicts faster rotation and smaller radius for early rotating galaxies and dust clouds.
- Third it suggests increased luminosity of early stars, and increased speed of stellar processes, if these are dependent on gravitational pressure.

Typically large stars have more pressure, burn hotter, and burn out faster. We expect early stars and galaxies to act gravitationally in "fast motion", like more massive stars or galaxies today.

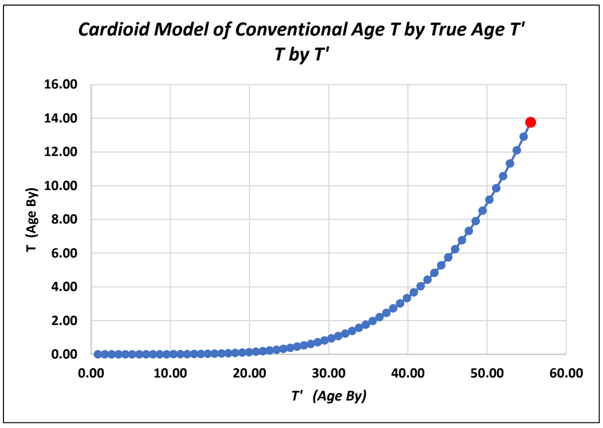


Figure 39. In the Cardioid model, the universe is some 55 By old in "real time". Yet it appears only 14 By in conventional time. What does this mean? We can think of *T* as the amount of "QM time" passing, and *T'* as the amount of "gravitational time" passing.

- In the first 20 By of *T',* only *20 years of conventional QM time T* passes.
- In the first 30 By of gravitational time, 1 By of QM time passes.
- In the next 25 By of gravitational time*,* 13 By of QM time passes.

The conventional time variable in physics in defined so that *the present rate of QM (primarily EM) processes is invariant in time, t.* This is set by an instrumentalist definition or convention.

- This sets *real time, t,* to *proper time, τ,* defined in *QM processes*.
- But the Cardioid model means *proper time* defined by *gravitational processes* changes like: *1/a*.

Conversely, in the Cardioid model variables, QM processes speed up with expansion.

- *QM processes* were slower in past in *true time, T'*.
- The gravitational constant *G'* is constant in *T'.*

Note there is a change in the form of mass-energy in the model. Rest-mass is transformed to "dark matter mass", which is an expansion of space.

Time for early galaxies to form.

Empirical NOW=(1-100)	To' | T'MAX (By)	A'To' (Radian)	Ro' | R'MAX (Bly)	dRo'/dT' (Ly/y)	Ho' (1/By)	To | TMAX (By)	Ro|RMAX (Bly)	dR/dT speed (Ly/y)
64	55.493	1.005	27.546	0.638	0.023	13.76	13.77	0.644
0.867	86.71	1.571	38.64	0.01	0.000	63.98	27.10	0.0
TMAX' = πRo'	86.5	RMAX = Vo^2Ro	38.757	TMAX = 3π/8 RMAX^2/Ro		63.855		
T' increments 0 - 100	*T' = true time Byrs.*	*A'T' = (π/2) (T'/T'max)*	*R' = R'max sin^2(A'T')*	*dR'/dT' Numeric*	*H' = (dR'/dT') / R'*	*T = f(T') = conventional time Byrs.*	*R = R'^2/2Ro'*	*dR/dT (ly/y)*
19	16.47	0.30	3.34	0.38	0.12	0.049	0.2	3.335
20	17.34	0.31	3.69	0.40	0.11	0.063	0.2	3.154
21	18.21	0.33	4.05	0.42	0.10	0.081	0.3	2.990
22	19.08	0.35	4.43	0.44	0.10	0.101	0.4	2.840
23	19.94	0.36	4.83	0.45	0.09	0.126	0.4	2.704
24	20.81	0.38	5.24	0.47	0.09	0.155	0.5	2.579
25	21.68	0.39	5.66	0.49	0.09	0.188	0.6	2.463
26	22.54	0.41	6.09	0.50	0.08	0.228	0.7	2.356
27	23.41	0.42	6.54	0.52	0.08	0.274	0.8	2.257
28	24.28	0.44	7.00	0.53	0.08	0.326	0.9	2.164
29	25.15	0.46	7.48	0.55	0.07	0.386	1.0	2.078

Figure 40. This shows the period *T* from about *63 My* to *326 My.*

The model suggests early galaxies have ample time to form in this period, from around *a ≈ 0.02*. This is only 300 My in ordinary time, but 6-7 By in model time. At the start of this period, around 60 My, *a* is about *1/50,* and in our simplest model, galaxies rotate some 2,500 times faster than the same galaxies today! $P = P_0a^2 = P^0/2{,}500$. And they will be *1/50th* their present radius: $R = R_0a = R_0/50$. At around 150 My, *a* is about *1/30,* and rotation is about 1,000 times faster.

So in the early period, we expect there will be compact fast-spinning globules or rings of dust or stars, forming proto-galaxies. We do not know the dynamics of their formation in our model, but it must resemble the standard model, appropriately re-scaled, fairly well. At some point dense turbulent clouds of hydrogen form stars and eventually coalesce into stable structures, some of which eventually become disk galaxies.

This process of gravitational collapse and aggregation into both stars and galaxies must happen much faster than in our current era, of weak gravity. By around 300-400 My, or *Z = 10-15,* there must have formed multiple, old-looking disk-like galaxies.

Test 5. Galaxy expansion with changing *G.*

> "One study looked at … the period approximately three billion years after the Big Bang. … At the infrared wavelengths detected by Webb, most of the massive galaxies looked much smaller than they did in Hubble images.

It seems they are talking about sizes smaller by about 50%. What happens in our model to the rotational speed and radii of gravitational systems, like spinning galaxies or star systems? There may be several equilibrium states that systems might evolve into, if the gravitational force slowly weakened. The first and simplest model, which is valid in the short-term with slow change, maintains Kepler's 3rd Law and makes: $r \rightarrow ra$ and: $P \rightarrow r/a^2$. However this does not take the production of dark matter into account, and in the recent past (from about 2By to the present), the variations are likely to be only on the scale of $a^{1/2}$ rather than *a*. But here we report the higher rate, on the Kepler model.

Table 2. At *T = 3 By, a = 0.35,* and in the simplest model, we expect that galaxies of similar mass to those today will be only 35% of their current radius. At *T = 5 By,* this may be 50%. They may also appear brighter than expected.

T = f(T') = conventional time Byrs.	*R = R'^2/2Ro'*	*a = R/Ro*
0.000	0.0	0.000
2.457	4.1	0.301
2.728	4.5	0.325
3.020	4.8	0.350
3.335	5.2	0.376
3.673	5.6	0.404
4.035	6.0	0.432
4.423	6.4	0.462
4.836	**6.8**	0.492

Indeed, galaxies are predicted in this simplest model to expand with the universe, whereas in the standard model they are locked in local gravitational orbits. However we think that the real solution is likely to be in-between, mainly because of the role of dark matter. These graphs show the maximal expansion rate.

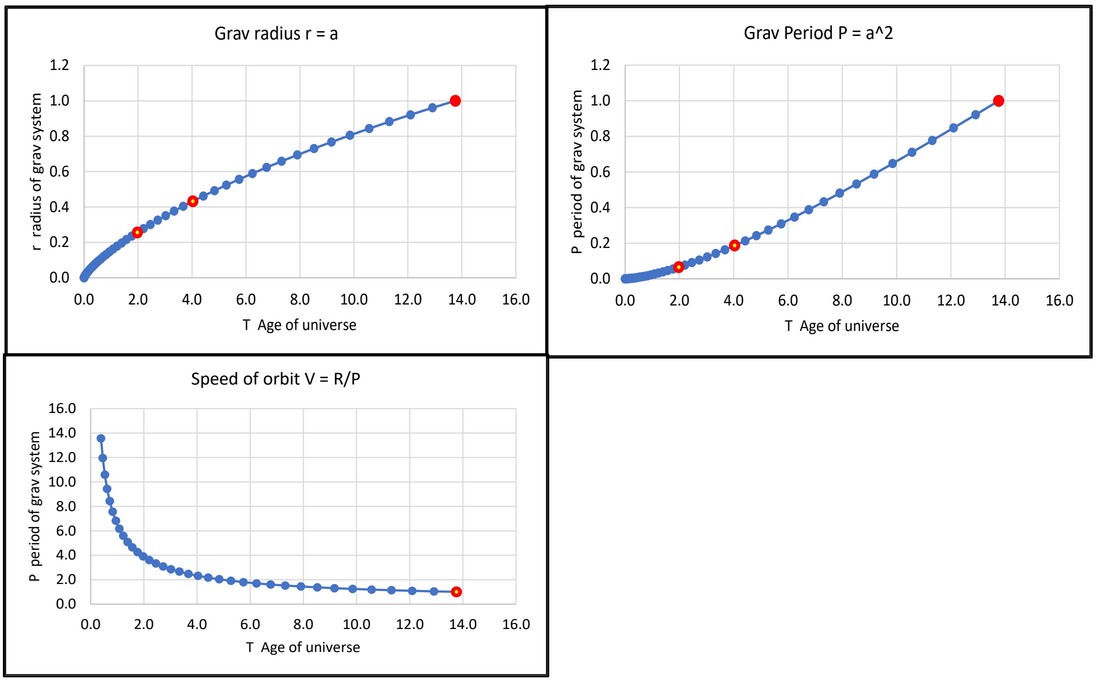


Figure 41. On the simplest model, galaxies were about third of their present sizes at about 3 By.
Figure 42. On the simplest model, galaxies rotated about ten times faster at 3 By.
Figure 43. On the simplest model, stars had about three times the orbital speed at 3 By.

These are general dynamics we analyse. But the process of galaxy formation and development is affected by the conversion of particle energy to dark matter, which slows the expansion and changes the shapes.

Dark Matter.

- Do stars or galaxies that formed in the very early period survive today?
- Which period did our present stars and galaxies form in?
- Did a generation of very large galaxies form and disperse?

The current *dark matter ratio* is about 85% of total mass on *average*, but it varies between galaxies on an individual basis, commonly between 80%-90% of the galactic mass, but can be more or less. Some small dwarf and elliptical galaxies have no DM, thought to be lost as a result of interactions with other galaxies. The critical question in our scenario is when the period of onset of galactic formation begins, when galaxies *retain their DM*, and are able to form halos. The general pattern and average indicates that:

- On average, about 7 times the mass energy has been transferred from the spatial potential energy, since the galaxies began to accumulate dark matter.

The first estimate is simply to take: *a ≈ 0.15,* and we get a time of about 1By or so for the onset of DM.

T' increments 0 - 100	*T' = true time Byrs.*	*T = f(T') = conventional time Byrs.*	*a = R/Ro*	*R = R'^2/2Ro'*	*dR/dT (ly/y)*	*T/T'*	*dT/dT'*
33	28.61	0.715	0.119	1.6	1.782	0.025	0.112
34	29.48	0.824	0.132	1.8	1.718	0.028	0.125
35	30.35	0.945	0.147	2.0	1.657	0.031	0.139
36	31.21	1.078	0.162	2.2	1.600	0.035	0.154
37	32.08	1.226	0.179	2.5	1.545	0.038	0.170
38	32.95	1.389	0.196	2.7	1.493	0.042	0.188
39	33.82	1.567	0.215	3.0	1.444	0.046	0.206

Figure 44. The period for a DM proportion of 80% - 90% is about: *a = [0.1, 0.2]* and: *T = [0.7, 1.4] By,* on the simplest assumption. Some small galaxies lose or fail to retain dark matter.

Note that in model time, *T' = 30 By,* not *1 By.* There has been the equivalent of billions of years of gravitational processes already passed. But for some reason, modern galaxies do not stabilise and begin to retain their dark matter, in the halos we observe or deduce today, until about 1 By.

Test 6. Speed of rotation and formation of disks.

"With the resolution of James Webb, we are able to see that galaxies have disks way earlier than we thought they did," says Allison Kirkpatrick, an astronomer at the University of Kansas in Lawrence. "That's a problem, she says, because it contradicts earlier theories of galaxy evolution."

On the Cardioid model, the rotational frequency is expected to be higher in the past, by between $1/a$ and $1/a^2$. This applies in the very early universe, when early galaxies coalesce faster and spin faster (from stronger *G*) and may be expected to form disks and massive galaxies much earlier than expected. The feature of mature or older disk or spiral galaxies is that it takes many rotations to create structures. Unless the galaxies rotate faster than on the standard model, there is no apparent way for them to form these disks.

Ferreira *et al.* 2022. "The JWST Hubble Sequence: The Rest-Frame Optical Evolution of Galaxy Structure at 1.5<z<8"

> "We present results on the morphological and structural evolution of a total of 4265 galaxies observed with JWST at 1.5<z<8 … this is the biggest visually classified sample observed with JWST yet,

~20 times larger than previous studies, and allows us to examine in detail how galaxy structure has changed over this critical epoch. All sources were classified by six individual classifiers using a simple classification scheme aimed to produce disk/spheroid/peculiar classifications, whereby we determine how the relative number of these morphologies evolves since the Universe's first billion years. Additionally, we explore structural and quantitative morphology measurements … and show that galaxies at z>3 are not dominated by irregular and peculiar structures, either visually or quantitatively, as previously thought. We find a strong dominance of morphologically selected disk galaxies up to z=8, a far higher redshift than previously thought possible. We also find that the stellar mass and star formation rate densities are dominated by disk galaxies up to z~6, demonstrating that most stars in the universe were likely formed in a disk galaxy. We compare our results to theory to show that … the Hubble Sequence was already in place as early as one billion years after the Big Bang.

This is a major contradiction of the standard model. In thousands of simulations of different scenarios, it has not previously produced this behaviour! Will cosmologists be able to get the standard models to produce this behaviour, now they know what the results are supposed to be? Perhaps not, because the behaviour is too extreme, but they will try. However, it is hardly robust if its predictions can be adjusted to match any new behaviours that unexpectedly arise.

The cardioid model, by contrast, naturally predicts such behaviour, with a mechanism intrinsic to the theory. It predicts this as a major difference with the standard model, but it must be taken as a qualitative prediction, as we cannot yet check it with detailed simulations.

Test 7. Guo 2022. Early-Middle period observed in detail.

The surprises continue in the early-middle period, at around 2-5 By or red shift of 1-3. This is the major period of modern galaxy formation, and it has been studied before, but now they find that structured barred spiral galaxies are well developed much earlier than they thought.

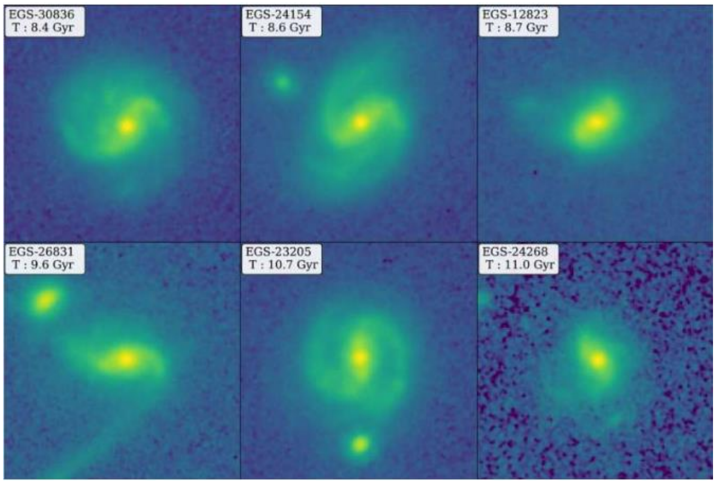


Figure 45. (Guo 2022). "Montage of JWST images showing six example barred galaxies, two of which represent the highest lookback times quantitatively identified and characterized to date. The labels in the top left of each figure show the lookback time of each galaxy, ranging from 8.4 to 11 billion years ago (Gyr), when the universe was a mere 40% to 20% of its present age. Credit: NASA/CEERS/University of Texas at Austin."

[James Webb telescope reveals Milky Way–like galaxies in young universe (phys.org)]

> pilot study we present six examples of robustly identified bars at $z > 1$ with spectroscopic redshifts, including the two highest redshift bars at $z \sim 2.136$ and 2.312, quantitatively identified and characterized to date. Our study complements *HST* studies in the last two decades that have mainly traced bars in the rest-frame optical out to $z \sim 1$.

Previous data, mainly from the HST data, was limited to around *z = 1,* and there is little data on the earlier period.

Guo 2022.

The match between red-shift and age is about 10% different to the Cardioid model.

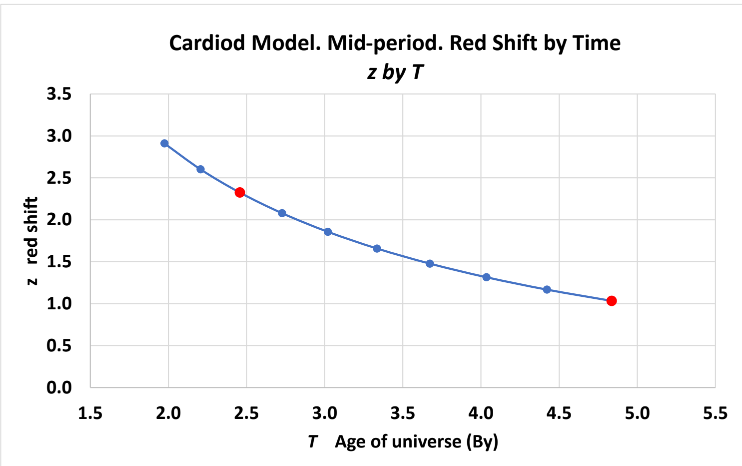


Figure 46. Cardioid model of *z* by age, *T,* from *z = 1 to 3.*

C.f. Guo, et al. 2022. Their red shifts for 8 – 10 By ago should be 9 – 11 By ago on the Cardioid model. The two highest *red shifts* of 2.14 – 2.31 should be a little over 11 By ago (not *10 By?)*. The red shift of $z = 1$ should be 9 By ago (not *8.4 By?)*.

> In this paper we assume the latest *Planck* flat ΛCDM cosmology with H_0 =67.36, Ω_m =0.3153, and Ω_Λ =0.6847 (Planck Collaboration et al. 2020). All magnitudes are in the absolute bolometric system (AB; Oke & Gunn 1983).

But note our Cardioid model fits for the present value of $H_0 = 72$ (cephids) while their model fits: $H_0 = 67.36$ (CMBR), the *Hubble tension,* and already a difference of 7.5%. Both models have at least a few percent error, and this is consistent. The interesting points are that bars are "already fairly strong and well-developed at … early cosmic times", the suggestion that the bars form early in "massive dynamically cold disks", and the question whether bars survive to the present epoch.

> The examples of stellar bars at $z \sim 1.1$–2.3 presented in our study have projected semi-major axes of ~ 2.9–4.3 kpc and moderate to high projected maximum ellipticities of ~ 0.41–0.53 in the rest-frame NIR, indicating they are already fairly strong and well developed at these early cosmic times. The barred host galaxies have stellar masses $\sim 1 \times 10^{10}$ to 2×10^{11} $M_\odot$, star formation rates of ~ 21–295 $M_\odot$ yr^{-1}, and several have potential nearby companions. Our finding of bars at $z \sim 1.1$–2.3 demonstrates the early onset of such instabilities and supports simulations where bars form early in massive dynamically cold disks. It also suggests that if these bars at lookback times of 8–10 Gyr survive out to present epochs, bar-driven secular processes may operate over a long time and have a significant impact on some galaxies by $z \sim 0$.

In any case, this supports the Cardioid model, with its predictions of early structure.

Test 7. Star chemistry and luminosity.

> 'Astronomers had thought that the process of chemical enrichment — in which stars fuse hydrogen and helium to form heavier elements — took a while, but the finding that it is under way in early galaxies "will make us rethink the speed at which star formation occurs", Kirkpatrick says.'

E.g. Trump (2022) report signs of oxygen at red-shifts of 5. Studies are also done on metallicity of stars and other features. The question here is about the first generation of stars, which originally combined only hydrogen and helium, fusing it in their nuclear cores, and subsequently exploding, creating heavy elements, such as planets are made from.

- The Cardioid model makes gravity stronger, and stellar nuclear fusion reactions that depend upon gravitational pressure must be expected to be faster for stars of similar mass.
- This speeds up star formation and is consistent with the new observations.

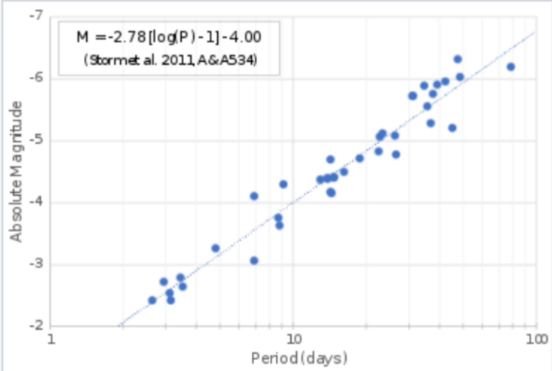
The processes of nucleosynthesis within stars should not change very much, as they are quantum mechanical processes, based on the standard particle model, and QM remains very similar until the very early period. But all these processes run faster and need to be remodelled in the new model.

Test 8. Star luminosity, period and distance.

Researchers have begun looking at luminosities with JWST.

"We compared the resultant Period-Luminosity relations to that of 49 Cepheids in the full period range including 38 in the longer period range observed with WFC3/IR on HST and transformed to the JWST photometric system (F200W, Vega). We find good consistency between this first JWST measurement and HST, and no evidence that HST Cepheid photometry is "biased bright" at the ~0.2 mag level that would be needed to mitigate the Hubble Tension…" . (Yuan 2022).

Cephid variable stars are central to *distance measurements* required to estimate the Hubble parameter from red shift data.



Period-Luminosity relation for Classical Cepheid variables.[1]

Figure 47. WIKIPEDIA. Period-luminosity relation.

(Yuan 2022) is mainly concerned to analyse the match between the HST and JWST, and confirms the data is reliable and consistent. This is what we expect, as the methods for measuring luminosity are effectively the same, and it is largely a matter of accounting for various factors, like dust. On the cardioid model however, the luminosities, periods and masses in the early universe are different, and this means we have to reinterpret distance calculations.

This is a key point of key interest to go forward, although we have not analysed it properly yet. We expect frequency to increase for Cephid variables in the early universe, by $1/\sqrt{a}$ or a similar factor. We do not know what happens to the luminosity. But the differences may cancel leaving current distance calculations unchanged. That would help explain why the standard and cardioid models match so well, without needing further interpretation of distance. This is a key question for analysing distance measurements required for the Hubble parameter on the Cephid variable method.

Until this and similar details are analysed properly, the Cardioid model cannot be confirmed. But we may take the various lines of evidence so far to be a strong case for taking it seriously enough to check. If consistency of the theory is verified it has a strong case to be considered as a realistic unified theory.

Discussion.

If the Cardioid model is physically wrong, the empirical matches illustrated here are just a mathematical coincidence. This is quite possible. There are coincidences in the data, such as the fact that the present Hubble time (*1/H)* is very close to the measured age (*T)*, and the time *A'T'* is very close to 1 radian, and: *tan(A'T') ≈ (*π*/2).* It may be that the model fit is a coincidence. This is the point: *both the Cardioid model match and the standard model match may be coincidences.* Can we really tell between them on the basis of the data? Or more exactly, can we really *verify the standard model, in preference to the Cardioid model, on the basis of the data?* The answer here is *No.* This means there is a viable alternative cosmology with completely different behaviour to the standard model! It removes *dark energy, the Big Bang singularity,* and the *accelerating expansion*.

But how can these questions remain so uncertain? After decades assuring us of their theory, has modern cosmology been telling us fairy tales all along? Well yes, it has, for the general reason that *the theoretical models they are representing as scientific fact are under-determined by data and not verified as facts at all.* The main reason so far has been limited empirical observations, which only cover limited periods in the past. But we can now see back as far as 300My, for the earliest *visible galaxies or stellar objects* so far detected. And we can see the CMBR in great detail, which was produced around 380Ky, and contains the earliest images of possible structures we can see. This data has improved tremendously over 30 years, with the HST bringing dark energy into view twenty years ago, and the JWST bringing early-universe galaxies into view in 2022, and lots of other telescopes and measurements of the CMBR, Hubble constant, Cephid variables, distance ladders, populations of galaxies, etc, filling in increasing detail.

The two models cannot be decided on their "best empirical fit" with astronomical data. Instead it comes down to the *fundamental theory* behind the models. The two different model behaviours ultimately reflect two different fundamental theories, which determine relationships in the background. The conventional model assumes the Friedmann equation, with mass-energy terms consistent with General Relativity. The different Cardioid model for *R(T)* must reflect a different assumption in the fundamental theory, and we see this explicitly. In other words, it is not primarily the *mass-energy contents of the universe* that is in question, as conventional cosmology assumes. It is the fundamental model, a solution to GR, which we determines underlying relationships.

But conventional cosmologists have insisted for decades now that their GR model is the only valid one. They can publish almost any kind of speculative proposals for new sources of mass-energy, as long as certain "fundamental algebraic properties" are retained in the super-structure of the theory. This refers to the so-called *relativistic covariance of equations,* often stated in terms of *invariance of form of laws w.r.t. observers or coordinate systems*. This is interpreted as the great and immutable truth of General Relativity, and it is why cosmologists believe their picture of the standard model is much more powerful than any empirical evidence they have for it, and more powerful than the alternative model we introduce here. However we will disagree.

Conventional cosmology has clung obsessively to its comfort blanket of GR, and ignored all alternatives to the fundamental theory. This is a kind of of catch-22. Almost no one has proposed any alternative fundamental theory, and theoretical physicists today have no idea what an alternative theory might even look like. All work in the field is done trying to fix up the conventional theory. No alternative theories have appeared, and the subject is increasingly forbidden, as *the vast investment in physics is in the conventional theories*.

But I emphasise that that *this choice to stick with conventional GR at all costs* has severe implications for the larger future of physics. Because the conventional choice forbids a priori any theories that have (i) changing fundamental constants, or (ii) physical relationships between local constants and expansion, or (iii) temporal or spatial variations in dimensionless ratios, or (iv) transformations of measurement variables to true variables for symmetries, or (v) extrinsically curved geometries in more than three dimensions of space.

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Where possible I have referenced free online sources including arXiv and other preprint sites. There are so many papers coming from JWST now it is hard to know where to stop, but I limited the review here to the twelve (2022) JWST studies referenced by Witze and a handful of relevant directly further papers. This gives adequate survey of the main points for our purposes here.

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This is an early presentation, now redundant. I was barred from posting further papers on the *philsci-archive* preprint site after that.

Acknowledgements.

Special thanks to Patricia Holster for support, encouragement and proofing of some material.

Appendices.

Appendix 1. Cardioid expansion function and transformations.

Note the capitalised variables are defined by the general boundary conditions: $dT = dt$ and $dT' = dt'$, with the special *boundary conditions* that: $T' \rightarrow 0$ *and* $T \rightarrow 0$ *at origin (Big Bang), and* $T_0 \rightarrow$ *current age (Now).*

Cardioid solution.

Cardioid solution is defined by this equation, in the model variables (dashed).

1. $R'(T)' = R'_{MAX} sin^2\left(\left(\frac{\pi}{2}\right)\left(\frac{T'}{T'_{MAX}}\right)\right) = R'_{MAX} sin^2(A'T')$

A' is a constant defined to convert time *T'* into an angle. *A'T'* is dimensionless, in radians:

2. $A' = \left(\frac{\pi}{2}\right)\left(\frac{1}{T'_{MAX}}\right)$ *= Constant.*

Model Hubble Parameter.

Differentiate (1):

3. $dR'/dT' = R'_{MAX}\, 2A' sin(A'T')cos(A'T')$
 $= 2A'R'cos(A'T')/sin(A'T')$
 $= 2A'R'/tan(A'T')$

H' is defined in the units of *(1/T')*:

4. $H' = (dR'/dT')/R'$

(3) and (4) mean:

5. $H' = 2A'/tan(A'T')$

The inverse *Hubble time* is the *Hubble age*:

6. $\frac{1}{H'} = \left(\frac{T'_{MAX}}{\pi}\right) tan\left(\frac{\pi T'}{2T'_{MAX}}\right)$

So the value at the present time is given by putting in T_0' for *T'*:

7. $\frac{1}{H'_0} = 2A' tan\left(\frac{\pi T'_0}{2T'_{MAX}}\right)$

Conventional Hubble Parameter.

It is a well-known coincidence that: $1/H_0 \approx T_0 \approx 13.8$ *By,* for the commonly agreed present values.

A similar coincidence in the Cardioid model is that the current time is close to: $\frac{T'_{MAX}}{T'_0} \approx \frac{\pi}{2}$.

This appears in the *best fit model.* It means the current angle in radians is 1:

$$A'T'_0 = \frac{2T'_0}{\pi T'_{MAX}} \approx \frac{2\pi}{\pi 2} = 1$$

In the numerical model we see: $A'T' = 1.005$. And: $tan(1) \approx \pi/2$, so: $tan(A'T_0') \approx \pi/2$. So from (5):

$$H'_0 = \frac{2\mathrm{A}'}{\tan(A'_0 T'_0)} \approx (2)\left(\frac{2}{\pi \mathrm{T}_0{}'}\right) = \frac{4}{\pi T'_0}$$

So we have this *predicted empirical relationship* for *H* from our model:

8. $H'_0 \approx \frac{4}{\pi T'_0}$ $H_0 \approx \frac{2}{\pi T_0}$

The *measured empirical value for the Hubble parameter* is larger by $\pi/2$.

With the *redshifts* and *expansion variable,* we expect the model variables to correspond quite directly to the measured variables. But the Hubble parameter is a combination of measurements, and we cannot expect the model *H* to match immediately without some additional scaling factor. It is bound to be needed, because there has been no account of the measurement of luminosity and distance mentioned yet. But what should it be? It may be a little difficult to analyse. But we know what its present value is: the factor $\pi/2$.

To keep the concepts distinct, we define the empirical measurement as *H*,* and we have the measurement observation:

$H^* \approx 1/T_0 = 1/13.8$ *By ≈ 72 (m/s)/MPSec* Empirical measured value of H_0.

And we have:

9. $H_0{}^* \approx \frac{\pi}{2} H_0$ Model interpretation of $H_0{}^*$

This is true for the present time, we generalise it to all times in a *functional way:*

10. $H^*(t) = \tan(A'T')H(t)$ Postulate: model interpretation of *H*.*

This means we multiply the direct model *H* by the extra factor *tan(A'T')* to predict the observed *H**.

- This fits with the standard model data-driven models very closely from the early past to the present.

Bakground. LNC relationship.

Note there is a primary relationship in the background, which is what enables us to connect quantum mechanics to the cosmology, and have a changing value of *G* in the first place. This is a "large number coincidence", which predicts the age of the universe from the constants in the general theory.

• T^*_0 is in: [*13.798, 13.84*] b.y.	[Time measurement]
• $(R_0/c\pi = h^2/2\pi^2 m_e m_p{}^2 Gc = 13.823$ *b.y.*	[Time - model prediction]

Extract. Holster 2014. The first equation states the measured age, the second equation states the value of a special combination of fundamental constants. This is the precise version in our model of one of Dirac's *large number coincidences*.

In the larger theory, the radius of the universe *R* equals the large dimensionless constant: $D = \frac{2\hbar c}{Gm^2}$ times the tiny QM particle-mass radius: $r = \frac{\hbar}{mc}$. We normally write it as the ratio: *R/r = D.* This uses the special value for the fundamental mass: $m^3 = m_e m_p^2$. The relationships should be written in dashed variables, but they hold at the present time for the constants in normal variables.

So: $$R = Dr = \frac{2\hbar^2}{Gm^3} = \frac{h^2}{2\pi^2 Gm^3} = 13.823\ Bly$$ TAU relationship.

Or the corresponding present time:

$$T_0 = cR_0 = \frac{2\hbar^2}{Gm_e {m_p}^2 c} = 13.823\ By$$ TAU relationship.

This gives the measured age of the universe, about 13.8 By, to a very close approximation. This is a genuine *large number coincidence.* Why does this special combination of fundamental constants, combining QM and GR, give precisely the measured cosmological age of the universe? It appears as purely coincidence in standard cosmology. We only note it in passing here, but it is this "coincidence" that makes the theory possible in the first place. Note a second independent coincidence, involving only electric-QM constants and not *G,* is the close equivalence of the fine structure constant: $\alpha = q^2/4\pi\varepsilon_0 hc = 1/137$, and the electron mass, in our natural units of *m*, i.e. $m_e/m = m_e/({m_p}^2 m_e)^{1/3} = (m_e/m_p)^{2/3} = 1/150$. As a fundamental relationship, this requires that the elementary electric charge is determined by the particle mass-ratio:

$$q = 2(\pi\varepsilon_0 hc)^{1/2}(m_e/m_p)^{1/3}.$$

The relation is stated with *h-bar* (which corresponds to using a *radius* variable). Replace *h-bars* with *h* to get a *circumference* variable:

$$\left(\frac{2}{\pi}\right)\frac{h^2}{Gm_e {m_p}^2 c} = T_0' = 2\pi T_0 = 2\pi\ x\ 13.823\ By = 86.7\ By$$

Or: $$\frac{h^2}{Gm_e {m_p}^2 c} = \left(\frac{\pi}{2}\right) {T_0}'.$$

So we get our present value as: $T_0 = \frac{T'_0}{2\pi} = 13.8\ By$ in the Cardioid solution.

Model interpretation of *H**.

We make the assumption (10) here as the basis of interpreting empirical results for the model. It fits perfectly well, and it is the only physical interpretation that can be taken for the model to work. So in general discussion we refer to *H** as the model prediction of the Hubble parameter. But we must still justify our interpretation of *H*,* in terms of measurement processes, which we need to reanalyse in the new model. Briefly, we conclude that:

- The: *dR/dT* term in: *H = (dR/dT)/R* is being correctly determined from red shift data.
- But the distance term *R* is not being correctly estimated from stellar luminosity measurements.
- In the past, *G* was greater by *1/a*, and on the simplest assumption, if this causes luminosities of stellar processes to increase by *1/a*, then distances are greater by: *1/√a* than estimated.

In any case this requires a detailed analysis of the *distance measurements inferred from luminosities of stars.* This is analysed further in Appendices.

As the main conundrum for the theory, several options have been considered.

- *Have we got the correct best-fit model?*
- *Can't we just match H* = H by varying the model parameters?*
- *Do we have any analytic errors of $\pi/2$ in our calculations?*
- *Does the geometric interpretation require a constant factor?*

We then need to turn to the physical interpretation of the measurement process, from the production of the light in distant stars to its subsequent measurement on Earth billions of years later.

- *Are red-shifts being interpreted accurately in our theory?*
- *Are distance measurements using distance ladders being measured accurately?*
- *Do distance estimates for the CMBR estimates have the same problem as cephid and other methods?*

Exercise. Set $HT = 1$.

- Can we set: T_0' to give: $T_0'H_0' = 1$?
- Suppose: $H_0T_0 = 1$, then: $H_0'T_0' = 2$.
- Then: $\frac{1}{H'_0} = \left(\frac{T'_{MAX}}{2\pi}\right) tan\left(\frac{\pi T'_0}{2T'_{MAX}}\right) = T'_0$.
- Or: $\frac{A'}{H'_0} = tan(A'T_0') = A'T'_0$
- But the only solution for: $tan(\theta) = \theta$ is at: $\theta = 0$, which is not physical.

Exercise. Set HT = 2/π.

- Suppose: $H_0T_0 = 2/\pi$, so: $H_0'T_0' = 2/\pi$, and: $1/H' = tan(A'T')/2A'$.
- So: $\frac{2A'}{H'_0} = tan(A'T_0') = \pi A'T'_0$
- Solution: $(A'T'_0) \approx$ 1.005 radians.

Scale function a(t).

We define a *scale function* $a'(T')$, which is analogous to $a(t)$ in the Friedmann equation.

We define $a'(T')$ as the ratio of the *universe radius at time T' divided by the radius at the current time* T_0'.

11. $a'(T') = \frac{R'(T')}{R'_0}$

From (1):

12. $a'(T') = \frac{R'_{MAX}}{R'_0} sin^2\left(\left(\frac{\pi}{2}\right)\left(\frac{T'}{T'_{MAX}}\right)\right)$

Note that by the same coincidence in $A'T'$, we have: $\frac{R'_{MAX}}{R'_0} \approx \frac{\pi}{2}$. So:

$$a'(T') \approx \left(\frac{\pi}{2}\right) sin^2\left(\left(\frac{\pi}{2}\right)\left(\frac{T'}{T'_{MAX}}\right)\right)$$

Along with the further coincidence that: $H_0 \approx 1/T_0$, we see how easy it is to get the factors of $\pi/2$ mixed up.

Transformations in *a(t).*

In terms of the *scale function:* $a'(T') = R'(T')/R'_0 = R'(T')/R'(T_0')$, the general transformations are:

13. $dr = a'dr'$, $dt = a'^2dt'$, $dm = a'dm'$ — Differential transformations
14. $c' = a'c_0$ and: $h' = h_0/a'$ and: $m' = m_0/a'$ and: $G' = G_0$. — Dynamics of constants.

This means the *values of constants are dynamic in the dashed system,* except for G', where: $G' = G_0$. The latter variables are used when we introduce mass and rest-mass.

- The essential requirement for our transformations to make physical sense is that: $c = c_0$ and: $h = h_0$ and: $m = m_0$, so these appear constant in ordinary variables, as usually defined instrumentally.

- But note this does *not* transform all the differences between the two models away.
- The Cardioid model contradicts the standard model by implying a changing value of *G.*
- But it means that locally the space-time metric matches SR for QMs.

Now *R* has the general solution:

15. $R = R'^2/2R'_0$

But *T* can only be determined by integration, when we have a solution for *a'(t')*:

16. $T = \int_{0+,\,T1} dt = \int_{0+,T'} a'^2\, dt'$

The Cardioid solution allows us to solve this.

Hubble parameter.

The normal Hubble parameter, *H* is defined in units of *(1/T)*:

17. $H = (dR/dT)/R$

To get *dR/dT* differentiate (11) by *T.*

18. $dR/dT = R'(dR'/dT)/R'_0$

Substituting (11) and (14) in (13):

19. $H = (R'(dR'/dT)/R'_0)(2R'_0/R'^2)= 2(dR'/dT)/R'$

Using the identity: $dR'/dT = (dR'/dT')(dT'/dT)$:

20. $H = (dR/dT)/R = 2H'(dT'/dT)$

At the present time,

21. $dT'/dT = 1$, so: $H_0 = 2H_0'$

T is solved in terms of *T'* our model by:

22. $T =(R'_{MAX}/R'_0)^2\big(3T'/8 - (T'_{MAX}/\pi)\, Sin(A'T')Cos(A'T') + (T'_{MAX}/8\pi)\, Sin(2A'T')Cos(2A'T')\big)$

Note: $(R'_{MAX}/R'_0)^2 = 1/sin(A'_0T'_0)^4$. And the *sin-cos* terms are zero are T'_{MAX}. So:

23. $T_{MAX} = (R'_{MAX}/R'_0)^2(3T_{MAX}'/8)$.

Then:

24. $H_0 = 2H'_0 = \left(\frac{2\pi}{T'_{MAX}tan(A'T'_0)}\right)$

Acceleration of *H.*

We obtain the acceleration of *H* in the Cardioid model.

Differentiating: $a' = (R_{max}/R_0)\, sin^2(A'T')$, and: $A' = (\pi/2T_{max})$ gives:

$$\begin{aligned} da'/dt' &= 2A'(R_{max}/R_0)\, sin(A'T')\, cos(A'T') \\ &= (\pi/T_{max})(R_{max}/R_0)\, sin(A'T')\, cos(A'T') \\ &= (\pi/T_{max})a'/tan(A'T') \end{aligned}$$

or:

25. $da'/dt' = 2A'a'/tan(A'T')$ Rate of change of expansion

Differentiating again:

$$d^2a'/dt^2 = 2A'/tan(A'T') + 2A'a'd/dt'(1/tan(A'T'))$$

$$= 2A'/tan(A'T') -(2A'^2/tan^2)(1+sin^2/cos^2)$$

$$= 2A'/tan(A'T') - 2A'^2/sin^2(A'T')$$

So: $$\frac{d^2a\prime(t')}{dt^2} = \frac{2A\prime^2}{sin^2(A'T')}\left(\frac{\sin^2(A'T')}{\tan(A'T')A\prime} - 1\right)$$

Use: $$\frac{2A\prime^2}{sin^2(A'T')} = \left(\frac{R\prime max}{R\prime_0}\right)\left(\frac{2A'^2}{a}\right)$$

So: $H' = (dR'/dt')/R' = (R'_0da'/dt')/(R'_0a') = (da'/dt')/a'$

26. $$H' = \frac{2A'}{tan(A'T')} = \frac{\pi}{T'_{MAX}}\frac{1}{tan(A'T')}$$

27. $dH'/dt' = -2A'^2/sin^2$

28. $$\frac{d^2H\prime(t')}{dt^2} = -\frac{2A'^2}{sin^2(A'T')} = -\left(\frac{R\prime max}{R\prime_0}\right)\left(\frac{2A'^2}{a\prime}\right)$$

We might define a complex version using real and complex parts for two lengths:

$$a' = \frac{R_{max}}{R_0}e^{2iA\prime T\prime} = \frac{R_{max}}{R_0}(\cos(2A'T') + i\sin(2A'T'))$$

Metric equations quick summary.

This is the *metric* for theories in different arrangements for comparison.

FLRW equation. (1) is the FLRW equation. (2)-(4) are different arrangements.

1	$c^2d\tau^2 = c^2dt^2 - a(t)^2dr^2$	*FLRW metric*
2	$d\tau/dt = \surd(1-a^2v^2/c^2)$	*FLRW time dilation*
3	$ds^2 = dw^2 + a(t)^2dr^2 = c^2dt^2$	*FLRW space-proper-time*
4	$\surd(dw^2 + a(t)^2dr^2)/dt = c$	*FLRW Speed version*

TAU equations. (1'-8') are the primary equations.

1'	$ds' = \surd(dw'^2+dr'^2)$	*TAU metric postulate*
2'	$ds'/dt' = a'(t')c_0$	*TAU speed postulate*
3'	$dw'dr' = dL_0{}^2= constant$	*TAU volume conservation*
4'	$dr' = dr_0/a'$	*TAU space postulate*
5'	$dw' = dw_0a'$	*TAU proper time postulate*
6'	$dt' = dt_0/a'^2$	*TAU time postulate*
7'	$dm' = dm_0/a'$	*TAU mass postulate*
8'	$c' = (dr'/dt') = a'c_0$	

(1'-8') are in *alternative variables,* which transform to standard variables, (1-4).

- In conventional time, T, all QM constants, including $c, h, m, \varepsilon_0, q,$ are invariant and G changes by $1/a$.
- In true time, T', all QM constants change, by simple powers of a, and G' is constant.
- In the *Cardioid or TAU model variables, G'* is invariant, and QM processes speed up as the universe expands, and $c' = ac_0,\ h' = h_0/a,\ m' = m_0/a,\ f' = a^2 f_0$.
- This ensures conservation of relativistic momentum: $m'c' = (m_0/a)(ac_0) = m_0c_0$.
- Note mass-energy is not conserved in the particle evolution: $m'c'^2 = a(m_0c_0^2)$ alone.
- The extra energy required for the particle mass is extracted from the velocity in R, the expansion slows, and the energy: $m'((dR'/dt')^2+(dr'/dt')^2) = m'((dR'/dt')^2+ c'^2)$ is conserved.
- This exchange between the manifold and particle retains some energy in the manifold which appears as dark matter, because it is a localisation of the spatial energy.

Friedmann and cardioid metrics quick summary.

This compares the TAU metric to the FLRW.

SR	$c^2d\tau^2 = c^2dt^2 - dr^2$	Minkowski metric.
GR	$c^2d\tau^2 = c^2dt^2/k(r)^2 - (dy^2 + dx^2) - k(r)^2dr^2)$	Schwarzschild. $\frac{1}{k^2} = 1 - \frac{2MG}{c^2r}$
FLRW	$c^2d\tau^2 = c^2dt^2 - a(t)^2dr^2$	Friedmann solution.
TAU	$c^2d\tau^2 = c^2dt^2/a(t) - a(t)dr^2$	In conventional variables, *a.*
<u>*Equivalent:*</u>	$a(t)c^2d\tau^2 = c^2dt^2 - a(t)^2dr^2$	In conventional variables, *a.*
TAU'	$c^2d\tau^2 = a'(t')^2c^2dt'^2 - a'(t')^4dr'^2$	In model variables, *a'.*

This requires: $c^2dt^2/a - adr^2 = a'^2c^2dt'^2 - a'^4dr'^2$

The solution is: $dt = dt'a'^2$ *and* $dr = dr'a'$ *and* $a = a'^2$ Transformations.

This is general in TAU. The Cardioid solution is a solution for *a* in TAU.

FLRW **Case 1. Light.**	$c^2d\tau^2 = 0.$	So: $dr/dt = c/a.$	(Red shift.)
FLRW **Case 2. Stationary mass.**	$dr/dt = 0.$	So: $d\tau/dt = 1.$	(*SR* limit.)
FLRW **Case 3. Moving mass.**	$dr/dt = v \ll c.$	So: $d\tau/dt = \surd(1 - a^2v^2/c^2).$	*SR + expansion.*

Cardioid **Case 1'. Light.**	$c^2d\tau^2 = 0.$	So: $dr/dt = c/a'^2 = c/a$	(Red shift).
Cardioid **Case 2'. Mass particle.**	$dr/dt = 0.$	So: $d\tau/dt = 1/\surd a$	(Changing-*SR* limit.)
Cardioid **Case 3'. Mass particle.**	$dr/dt = v \ll c.$	So: $d\tau/dt = (1/\surd a)\ \surd(1 - a^2v^2/c^2)$ $\approx (1/\surd a)(1 - a^2v^2/2c^2)$	

Appendix 2. Physical effects.

Red Shift.

The *red shift* of light from earlier times measures the *scale factor of expansion, $a'(T')$,* and as we have a model for the *expansion with time,* it lets us infer the time. We assume that at the present time: T_0', light is produced at a natural frequency and wavelength, by a natural chemical process, with a distinctive wavelength:

$$\lambda_0' = c_0'/f_0'$$

At the earlier time T', light is produced with *frequency f', wave-length λ', and wave speed c',* so:

$$\lambda' = c'/f'$$

The Cardioid model provides the key relationships:

$$c' = a'c_0$$

$$f' = a'^2 f_0$$

So:

$$\lambda' = c'/f' = c'_0 f_0'/a' = \lambda_0'/a'$$

- This is the *true wave-length* of the original light when it is produced at its origin at T'.
- It means the true wavelengths were longer in the past, when: $1/a' > 1$.

But the wavelength also stretches as space expands.

- Space stretches by the factor: $a'(T')$ going from: T'_0 to T'.
- Space stretches inversely by: $1/a'(T')$, going from T' to T'_0.

So when the light reaches us from T' in the past, its wavelength is further increased:

$$\lambda_0^* = \lambda'/a' = \lambda_0'/a'(T')^2$$

Constants match at the present moment: $\lambda_0' = \lambda_0$. And there is a general solution for a:

$$a'(T') = \sqrt{a(T)}.$$

So the *change in wavelength* in conventional terms is determined by:

$$\lambda^* = \lambda_0/a(T)$$

The *red shift* is defined as the normalised change in wave-length: $z = (\lambda^*-\lambda_0)/\lambda_0$, or:

$$z = (\lambda^*/\lambda_0 - 1) = 1/a(T) - 1$$

This is the model prediction for the observed wavelength of the light from T when we measure it *now*.

This takes into account both the difference in process speeds and the stretching of space over time.

This is the same result as in the standard model. In normal variables, the light is produced at T with the same *speed $c = c_0$, frequency $f = f_0$, and wavelength $\lambda = \lambda_0$,* in the same process as when it is produced now. Over time, from T to T_0, space stretches by: $1/a(t)$, so the wavelength also stretches by: $\lambda^* = \lambda_0/a(T)$.

So the two models have a consistent interpretation of the *red-shift.*

Stellar luminosity as a measure of distance.

We need to know the difference TAU makes to the standard model luminosity and distance.

- If a certain type of star has a standard luminosity (total power output) *L*, then its brightness at distance *d* is approximately related by: $B = L/d^2$, or: $d = \sqrt{(L/B)}$. (Note this is true at smaller distances, at large distances we must take the curvature into account.)
- This is used with Cephid variable stars, by measuring the brightness *B* directly (and adjusting for effects like dust to get *true brightness*); and estimating the luminosity by measuring the *period* directly, and using the almost-linear relation between period and luminosity.

Now in stellar processes *where luminosity is positively related to G,* similar stars would have *greater luminosity* in the past than they do today. So this may cause us to overestimate distances. But for the key example of Cephids, the luminosity is calibrated to the *period*, which also changes. These changes tend to cancel. E.g.

- If true luminosity is given by: $L^* \approx L/\sqrt{a}$, *and true period is given by:* $P^* \approx P/\sqrt{a}$, the effect on distance measurements cancels, because of the approximately linear relation between *P* and *L*.

If only the luminosity changed, the true distance might have to be modified something like: $d^* = d/a^{1/4}$. This significant, but not very large for observations within $z = 1$. E.g. for $z = ½$ the distance should be about 10% less. This is the main realm of observations used to determine the Hubble constant. For this: $H = (dR/dt)/R$, the first term is from the red shift and appears correct, but the distance term: $1/R$ is measured by luminosity distance, *d,* and: $d \rightarrow d/ a^{1/4}$ would give: $H \rightarrow (dR/dt)/(R/\sqrt{a}) = Ha^{1/4}$

Effects may vary for different star types, depending on how their processes are affected by greater gravitational pressures with the same matter density. Stellar and galactic dynamics may be affected in complex ways. A similar question arises for gravitational waves. E.g.

> Gravitational waves originating from the inspiral phase of compact binary systems, such as neutron stars or black holes, have the useful property that energy emitted as gravitational radiation comes exclusively from the orbital energy of the pair, and the resultant shrinking of their orbits is directly observable as an increase in the frequency of the emitted gravitational waves. To leading order, the rate of change of frequency f is given by[16][17]:38
>
> $$\frac{df}{dt} = \frac{96\pi^{8/3}(G\mathcal{M})^{\frac{5}{3}} f^{\frac{11}{3}}}{5\,c^5},$$
>
> where G is the gravitational constant, c is the speed of light, and $\mathcal{M}$ is a single (therefore computable[a]) number called the chirp mass of the system, a combination of the masses (m_1, m_2) of the two objects[19]
>
> $$\mathcal{M} = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}}.$$
>
> By observing the waveform, the chirp mass can be computed and thence the power (rate of energy emission) of the gravitational waves. Thus, such a gravitational wave source is a **standard siren** of known loudness.[20][17]

("Gravitational waves as a measure of distance", Wikipedia, Hubble Constant.) This equation for the rate of change in frequency has a term in $G^{5/3}$, but how do we calculate the effect in our model? How generalisable are the rules for treating time and distance estimates for different observational methods?

Kepler's Law. Period and radius.

Gravity is stronger in the early universe in our model. This suggests that stars and galaxies will form faster and rotate faster, with altered radii. We can generally work in our normal variables with these rules:

- The gravitational constant is inverse to the expansion: $G = G_0/a$.
- *m and r* and other terms are invariant, as in ordinary physics.
- The laws of gravity and quantum mechanics are almost the same in conventional variables.

Since *gravitational energy or force* is normally proportional to *G* as in: $E = mMG/r$, and: $F = mMG/r^2$ we may expect they change proportionally to *1/a*. But if we apply slowly changing *G* to a rotating galaxy or orbiting planet, it can form a new stable orbit by changing the rotation speed and orbital radius.

Kepler's 3rd law for the period of a circular orbit of radius *R* around a large central mass *M* is:

	$P_0 = 2\pi\sqrt{(R_0^3/M_0G_0)}$	Kepler's Law Static

This is for a system now. The Cardioid model means we can normally rewrite equations in conventional variables the same as usual, for all the terms: $c, h, m_e, m_p, \mu_0, \varepsilon_0, q$, <u>except</u> *G,* which is dynamic:

	$G(t) = G_0/a(t)$	*G* dynamic

So Kepler's law changes to:

	$P(t) = 2\pi\sqrt{(aR^3/M_0G_0)} = P_0\sqrt{a}$	*Kepler's Law, Dynamic G*

We calculate it in in the model variables to make sure they match.

	$P' = 2\pi\sqrt{(R'^3/M'G')}$	Kepler's Law, Model Variables

In model variables, *G'* is constant, and the other quantities change.

	$G' = G_0$	Model dynamics for *G'*.
Also:	$M' = M/a'$	Model transformation for mass
Also:	$R' = R/a'$	Model transformation for space
And:	$P' = P/a'^2$	Model transformation for period
So:	$P' = 2\pi\sqrt{(a'R'^3/MG_0)}$	Replace *M'*
So:	$P' = 2\pi\sqrt{(R^3/a'^2M_0G_0)} = (1/a')2\pi\sqrt{(R^3/M_0G_0)}$	Replace *R'*
So:	$P = 2\pi a'\sqrt{(R^3/M_0G_0)} = P_0\sqrt{a}$	Replace *P'*

Use: $a' = a^{1/2}$ to get Kepler's law/

	$P(t) = 2\pi a^{1/2}\sqrt{(R(t)^3/M_0G_0)}$	*Kepler's Law, Dynamic G*
If: $R = R_0$:	$P = P_0 a^{1/2}$	*For fixed R, periods increase by* $a^{1/2}$
	$R(t) = P(t)^{2/3}a^{-1/3}(M_0G_0/4\pi^2)^{1/3}$	*Kepler's Law, rearranged for Radius*
If: $P = P_0$:	$R = R_0/a^{1/3}$	*For fixed P, radius decreases by* $a^{1/3}$

Squaring and dividing:

	$P^2/R^3 = a(4\pi^2/M_0G_0)$	Kepler equation.

If we assume there are solutions: $P = P_0a^X$ and: $R = R_0a^Y$ then:

	$P^2/R^3 = a^{2X-3Y}P_0^2/R_0^3 = a^{2X-3Y}(4\pi^2/M_0G_0)$	For *X, Y* solutions.
So:	$2X - 3Y = 1$	Kepler Solution.
And:	$X = (1+3Y)/2$	$Y = 0, X = 1/2$
And:	$Y = (2X-1)/3$	$X = 0, Y = -1/3$

Gravitational orbits. Special cases.

The Kepler law: $P^2/R^3 = a(4\pi^2/M_0G_0)$ applies to a central mass orbit, of a small mass *m* around a large mass *M,* e.g. a planet around a star. It is similar for other rotating gravitating systems, within approximations.

- Similar laws apply for stars in rotating disk or spiral galaxies.
- Similar laws apply for two stars rotating around each other.
- We take the objects to rotate around the *center-of-mass* of the whole system.
- We take the system center-of-mass to be stationary and non-accelerating.

Kepler's law allows stable periodic orbits at different radii, reflecting the kinetic energy-potential energy. How will stable orbits at one time in our universe evolve with expansion as *G grows weaker?*

Note the *period and radius* are what we need to consider, as mass is essentially irrelevant to the orbits.

- Two planets of different masses could have the same orbit around the sun.
- Two planets of the same mass can have different orbits.
- Gravity works equivalently on all masses (Equivalence principle).

This means it is open how the relationship between *R* and *P* might alter in the future. First we illustrate three simple cases. We mention the trivial solution of a fixed radius to start, but it is not applicable to a system of free gravitating rotating bodies if they are connected by a rigid radius that transmits forces.

$2X – (0) = 1$ Kepler condition.
$X = ½ , Y = 0$

$P = P_0\surd a$ and: $R = R_0$

Case (1): $X = Y$.

$2X – 3Y = -X = 1$ Kepler condition.
So: $X = Y = -1.$
$P = P_0/a$ and: $R = R_0/a$

This preserves ***linear momentum*** in the conventional variables, because

$R/P = (R_0/a)/(P_0/a) = R_0/P_0 = V_0 = constant$

Then the *linear momentum*: ***p*** = ***V****m* is constant for each element of orbiting mass.

But *angular momentum* now has a factor in *a*.

$L = VmR = L_0/a$ Angular momentum not invariant.

The kinetic energy is constant since *V* is constant (for each element and for the whole system):

$E_k = ½\ mV^2 = ½\ mV_0{}^2 = E_{K0}$ Kinetic energy constant.

The gravitational PE is constant as the change in *G* and *R* cancel:

$E_G = -MmG/R = -MmG/R = E_{G0}$ Gravitational PE changes

So that: $E_K + E_G = 0$ Conservation of energy

Case (2): $X = 2Y$

This appears to be the realistic case.

$2X – 3Y = Y = 1$ Kepler condition.

So: $Y = 1, X = 2$

$P = P_0a^2$ and: $R = R_0a$

This preserves *angular momentum* (for each element of orbiting mass), because

$V = R/P = (R_0a)/(P_0a^2) = R_0/P_0a = V_0/a$ Speed decreases.

So: $mVR = m(V_0/a)(R_0a) = mV_0R_0$ Angular momentum is preserved.

But the *linear momentum* is decreasing for each element of orbiting mass.

$mV = mV_0/a$ Linear momentum decreases.

However change in total linear momentum of the system is zero. Changes cancel out across the system. The underlying mechanics reconciles the process with a local transfer of momentum through space.

What does vary over time is the kinetic energy, for each mass-element and for the system total:

$E_k = ½\ mV^2 = ½\ mV_0{}^2/a^2 = E_{K0}/a^2$ Kinetic energy reduces

The gravitational potential energy varies by the same amount in the negative:

$E_G = -MmG/R = -MmG/Ra^2 = E_{G0}/a^2$ Gravitational PE changes

Remembering that now both *G* and *R* change (because *R* is a gravitational radius in this case), so that in total:

$E_K + E_G = 0$ Conservation of energy

Special case 3: $X = -Y$.

$2X + 3X = 1$ Kepler condition

so: $X = 1/5,\ Y = -1/5$ Period and radius by $a^{0.2}$

$P = P_0a^{1/5}$ and: $R = R_0a^{-1/5}$ Solution

$V = 2\pi R/P = V_0/a^{2/5}$ Speed decreases

$L = L_0/a^{1/2}$ Angular momentum decreases

This makes the speed and momentum decrease.

The second case (2): $R = R_0a$ and $P = P_0a^2$, is of most interest. It matches *the metric expansion* of space and time in our model, with no other forces applied to the gravitating system to change its properties or dimensions. It conserves angular momentum. It conserves total linear momentum. But it does not conserve *absolute kinetic energy.* This phenomenon is like "disappearing kinetic energy".

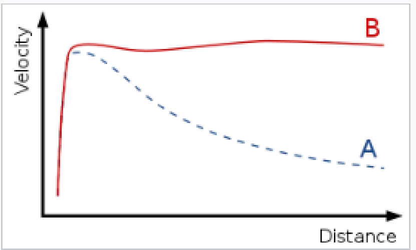
- The energy equations in conventional variables appear to remain in balance at any moment, and there appears to be zero net change of energy.
- But kinetic energy is nonetheless disappearing from the system! Where is it going?
- Somehow it must be going in the energy of space because that it all there is!
- Is this related to dark matter?

How is the kinetic energy of the mass particle being transferred into potential energy? It is stored in the *strain* of the space manifold. The expansion therefore transfers a proportion of kinetic *mass-energy, mc^2,* into elastic strain. Linear momentum of the elementary particles is not invariant, as there is a force or acceleration being applied to them, through the stretching of space. Linear kinetic and potential energy are being exchanged between particles and space. But we want to keep angular momentum invariant, because there is no torque applied in the process, as the forces are radially symmetric.

Galactic rotation and dark matter.

We can see that the Cardioid model offers potential to explain some anomalous phenomenon of early galaxies. But for the main era of development of present galaxies, beginning about 1-2 By, *dark matter* has to play a central role in the evolution, as it does in the standard theory.

Figure 48. Wikipedia. The orbital speed of stars in the arms of spiral galaxies is one of the most famous anomalies in physics. The speeds are much faster than would be expected from the central mass of the stars and other visible matter alone. Stars have "flat" speed curves, instead of the speed decreasing with radius.



Rotation curve of a typical spiral galaxy: predicted (**A**) and observed (**B**). Dark matter can explain the 'flat' appearance of the velocity curve out to a large radius.

What keeps the stars in orbit at such high speeds? How did they get into these high-speed orbits? The standard theory now is that halos of *dark matter* surround most galaxies, and does most of the work of holding them together.

Dark matter is needed to provide about 85% of the mass and gravitational forces for most galaxies. But it is undetectable and no one knows what it is. It is dispersed like a thin invisible fog. It forms giant halos around galaxies. It does not concentrate at the centre like ordinary matter. It is a central mystery of cosmology.

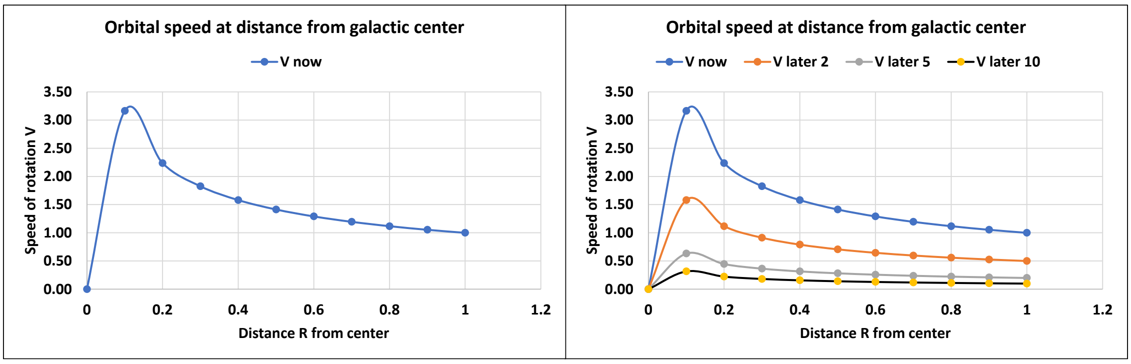
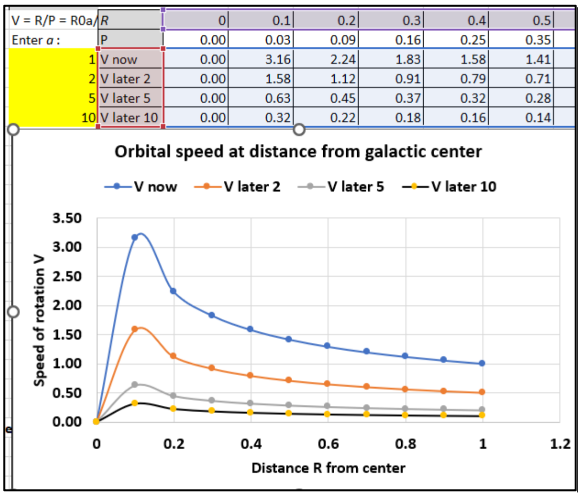


Figure 49. Left. The *expected distance-speed relationship* from galactic center for stable orbits. Scaled to make *V = 1 at r = 1*. Right. Evolution of the curve over time in the expanding Cardioid model universe. As *a* increases, the curve does not change shape, although it may look flatter to the eye.

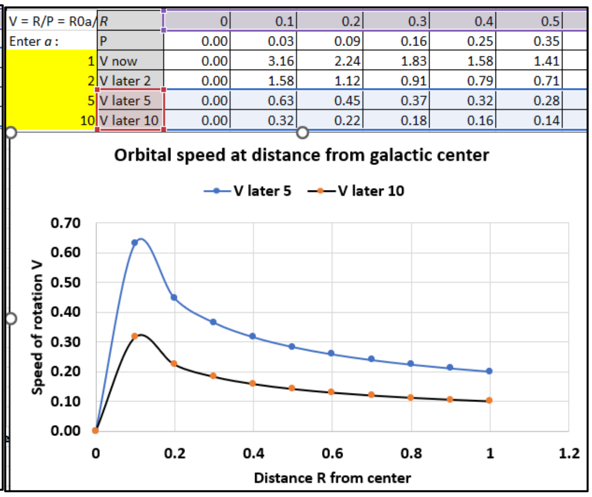
If we model a conventional galaxy with stars rotating a central mass, obeying Kepler's law for a stable orbit, we get the (blue) *radius-speed* graph. The shape does not change in the expansion, and this does not explain the flat speed curves of galaxies today.

For this graph, we simply take: $V = R/P$ and $P = R^{3/2}$ so: $V = (R/R^{3/2}) = 1/R^{1/2}$. When: $R \rightarrow Ra$ and $P \rightarrow Pa^2$, we have: $V = 1/aR^{1/2}$.

I emphasise that the effect cannot be achieved simply by the transformation for the expansion.



V = R/P = R0a/	R	0	0.1	0.2	0.3	0.4	0.5
Enter *a* :	P	0.00	0.03	0.09	0.16	0.25	0.35
1	V now	0.00	3.16	2.24	1.83	1.58	1.41
2	V later 2	0.00	1.58	1.12	0.91	0.79	0.71
5	V later 5	0.00	0.63	0.45	0.37	0.32	0.28
10	V later 10	0.00	0.32	0.22	0.18	0.16	0.14



V = R/P = R0a/	R	0	0.1	0.2	0.3	0.4	0.5
Enter *a* :	P	0.00	0.03	0.09	0.16	0.25	0.35
1	V now	0.00	3.16	2.24	1.83	1.58	1.41
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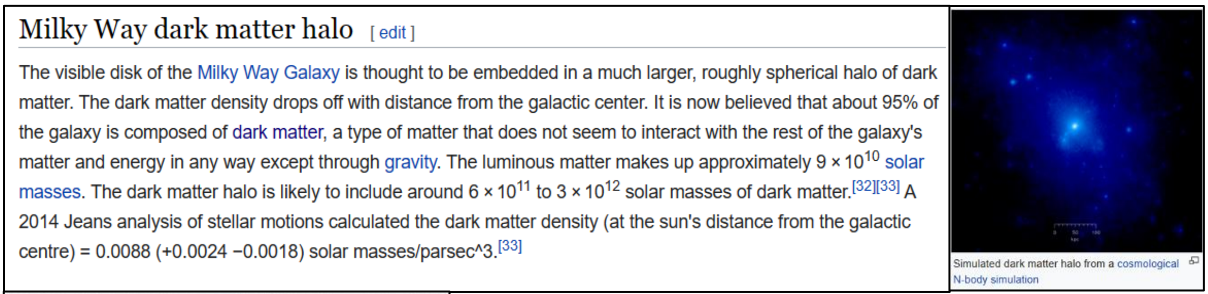
5	V later 5	0.00	0.63	0.45	0.37	0.32	0.28
10	V later 10	0.00	0.32	0.22	0.18	0.16	0.14

Figure 50. Right shows the two curves at the bottom of the graph on the left. The shape does not change shape over time, it is simply being scaled by *a*.

This assures us our model is consistent is Kepler's law. But we cannot explain the flat speed curve with a conservative time transformation. We know from cosmology that it requires *dark matter.*



Milky Way dark matter halo [edit]

The visible disk of the Milky Way Galaxy is thought to be embedded in a much larger, roughly spherical halo of dark matter. The dark matter density drops off with distance from the galactic center. It is now believed that about 95% of the galaxy is composed of dark matter, a type of matter that does not seem to interact with the rest of the galaxy's matter and energy in any way except through gravity. The luminous matter makes up approximately 9 × 10^{10} solar masses. The dark matter halo is likely to include around 6 × 10^{11} to 3 × 10^{12} solar masses of dark matter.[32][33] A 2014 Jeans analysis of stellar motions calculated the dark matter density (at the sun's distance from the galactic centre) = 0.0088 (+0.0024 −0.0018) solar masses/parsec^3.[33]

Simulated dark matter halo from a cosmological N-body simulation

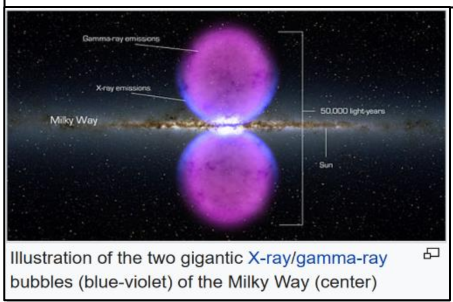


Illustration of the two gigantic X-ray/gamma-ray bubbles (blue-violet) of the Milky Way (center)

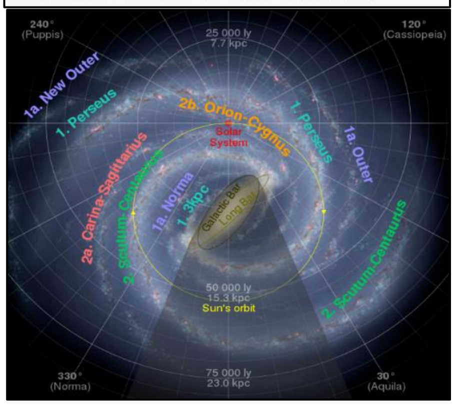


Figure 51. Wikipedia. Almost everything about dark matter is inferred from computer simulations! Only the speed of stars is observed, from their red-shifts. Estimates of DM are only within a factor of about two, e.g. the DM in our Milky Way galaxy is estimated to have an estimated mass of 7 *to 15 times* the mass of visible matter.

It is thought dark matter forms in roughly spherical *halos around galaxies,* and this is required for the peculiar velocity distributions. This remains similar in our theory, which is like the standard theory on the local scale.

The changing strength of gravity in our theory does not remove the need for dark matter. But it offers a mechanism for dark matter, which appears required to balance the massive transfer of energy from particles to space that is happening in our model.

Transfer of energy between mass and space.

In our model energy is stored in the elasticity of space, which is in tension, and supports elastic waves, including EM waves, and gravitational waves, and particle mass-waves, which are *de Broglie* waves, or QM waves. As the universe stretches, the kinetic and potential energy components are exchanged, with an energy exchange between particles and space.

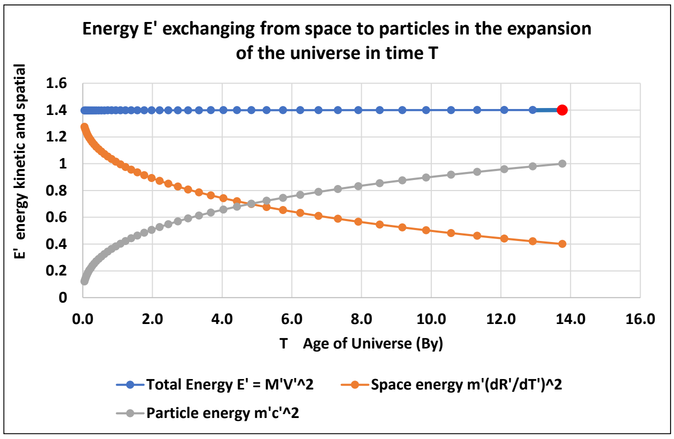


Figure 52. Transfer of energy from space to local speed in *c'* in the expansion. Expansion converts motion in *R* to motion in *c.* This balances energy. Total mass is: $m' = m_0 a' = m_0 + m_0(a'-1)$. The first term is what we measure, the second is invisible.

This exchange is intrinsic to the process, like exchange of potential and kinetic energy in ordinary gravity. But potential energy is an abstract concept, while we have a physical interpretation, an "energy well." It is kinetic energy in the new spatial dimension of expansion. It exchanges energy with particles in moving in the normal dimensions.

- The flat speed curve is not stable without a change in the mass distribution.
- The conversion of kinetic energy creates *dark matter* which slows the expansion, transfers energy into space locally around galaxies, and flattens the speed curves.

So dark matter is dynamic. The simplest proposal is to make dark matter proportional to *a*, since that is the mass dilation factor. Then *the time when galaxies were able to retain their dark matter halos* is what determines the ratio now. Dark matter and ordinary matter, or their equivalent energy and momentum, are conserved as a whole, all together, but in the development of the universe, they are both *localised* into structures, primarily galaxies. This was presumably under way in the very early universe, with the "recombination" era and photon decoupling about the earliest definite events, at around 380,000 years.

Recombination (cosmology)

From Wikipedia, the free encyclopedia

In cosmology, **recombination** refers to the epoch during which charged electrons and protons first became bound to form electrically neutral hydrogen atoms. Recombination occurred about 370,000 years[1][notes 1] after the Big Bang (at a redshift of $z = 1100$[2]). The word "recombination" is misleading, since the Big Bang theory doesn't posit that protons and electrons had been combined before, but the name exists for historical reasons since it was named before the Big Bang hypothesis became the primary theory of the creation of the universe.

Recombination involves electrons binding to protons (hydrogen nuclei) to form neutral hydrogen atoms. Because direct recombinations to the ground state (lowest energy) of hydrogen are very inefficient[clarification needed], these hydrogen atoms generally form with the electrons in a high energy state, and the electrons quickly transition to their low energy state by emitting photons. Two main pathways exist: from the *2p* state by emitting a Lyman-a photon - these photons will almost always be reabsorbed by another hydrogen atom in its ground state - or from the *2s* state by emitting two photons, which is very slow.[clarification needed]

This production of photons is known as decoupling, which leads to recombination sometimes being called **photon decoupling**, but recombination and photon decoupling are distinct events. Once photons decoupled from matter, they traveled freely through the universe without interacting with matter and constitute what is observed today as cosmic microwave background radiation (in that sense, the cosmic background radiation is infrared [and some red] black-body radiation emitted when the universe was at a temperature of some 3000 K, redshifted by a factor of 1100 from the visible spectrum to the microwave spectrum).

Figure 53. Wikipedia. The recombination era is long before galaxies could form, but in our model, dark matter creation started as soon as electrons and protons formed.

Dark energy and particles.

"Dark energy" is said to be an invisible substance that uniformly fills space. In fact it has no physical model: it is just an additional parameter in the equation governing the expansion. This has four terms for the acceleration of the expansion function *a*, in: A/a^2, B/a, Ca^2, and D. The first two represent *mass* and *radiation,* then *dark energy* and the *cosmological constant.*

The standard model (ΛCDM) has a *currently decreasing rate of expansion*, not an increasing rate of expansion, as often stated. But it has a positive acceleration term in the rate, which will eventually make it positive. And it is not decreasing by as much as the *CDM universe (cold dark matter universe).* The lambda term or dark energy that acts like a pressure outwards, accelerating the expansion. It is supposed to be *uniformly distributed throughout space.* It is not conserved like energy.

- The matter-energy breakdown is about: 68-74% Dark energy + (26% Dark matter+ 5% QM matter).
- Only 5% of the universe mass-energy is ordinary matter, that interacts through the known QM forces, the EM, weak and strong nuclear forces.
- The primary *long-lived particles,* that make up practically all of the long-lasting interacting matter and radiation in our environment, are just five types: *the photon, neutrino, electron, proton, neutron*.
- Note neutrons without protons are unstable. Neutrons are unstable outside the nucleus, with a half-life of about 10 minutes. Now it is also thought that neutrinos are unstable. The *photon, electron and proton* now appear as the only *eternal particles* in the standard model.
    - Lepton family. The muon and tau are high-energy versions of the electron, they are intrinsically unstable, but still essentially long-lived particles. C.f. neutrons.
    - They can have indefinitely long lifetimes at sufficiently high speeds. Muons are produced in our atmosphere by cosmic rays, and they travel substantial distances (100m) between production and decay. They also all have anti-particle versions.
    - Neutrinos also come in three types, with anti-particles, and these *families and anti-particles* are all considered equally real long-lasting particles.
    - Anti particles are produced in small amounts, but ordinary matter overwhelmingly dominates in our environment.
- Note other particles in the Standard Model, including mesons, are less stable again, and only mediate in short-lived processes, involving the weak force or strong forces. These interactions are on the scale of the proton radius, about 10^{-15}m, about a thousandth of the EM radius of about 10^{-12}m, for EM interactions in the atom.
- Quarks provide a model for protons and neutrons, but they are not observable as particles. They cannot be observed by themselves, only in the stable combinations of protons and neutrons, or in the transitory combination of two quarks in mesons.
- This is the main division between the *five real-world particles* and *elementary particles.*
- Note that in terms of causality, the weak and strong forces, which are *local forces,* do not transmit causal influences over distances greater than the nuclear radius.
- Causal influences are transmitted by the *EM force,* or *photons, and gravity*.

Appendix 4. Standard Model Friedmann equations.

All extracts here from WIKIPEDIA.

The Friedmann equations start with the simplifying assumption that the universe is spatially homogeneous and isotropic, that is, the cosmological principle; empirically, this is justified on scales larger than the order of 100 Mpc. The cosmological principle implies that the metric of the universe must be of the form

$$-\mathrm{d}s^2 = a(t)^2\, \mathrm{d}s_3{}^2 - c^2\, \mathrm{d}t^2$$

where $\mathrm{d}s_3{}^2$ is a three-dimensional metric that must be one of **(a)** flat space, **(b)** a sphere of constant positive curvature or **(c)** a hyperbolic space with constant negative curvature. This metric is called Friedmann–Lemaître–Robertson–Walker (FLRW) metric. The parameter k discussed below takes the value 0, 1, −1, or the Gaussian curvature, in these three cases respectively. It is this fact that allows us to sensibly speak of a "scale factor" $a(t)$.

FLRW Extract 2. This definition is given in the negative.

There are two independent Friedmann equations for modelling a homogeneous, isotropic universe. The first is:

$$\frac{\dot{a}^2 + kc^2}{a^2} = \frac{8\pi G\rho + \Lambda c^2}{3}$$

which is derived from the 00 component of Einstein's field equations. The second is:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda c^2}{3}$$

which is derived from the first together with the trace of Einstein's field equations (the dimension of the two equations is time^{-2}).

a is the scale factor, G, Λ, and c are universal constants (G is Newton's gravitational constant, Λ is the cosmological constant with dimension length^{-2}, and c is the speed of light in vacuum). ρ and p are the volumetric mass density (and not the volumetric energy density) and the pressure, respectively. k is constant throughout a particular solution, but may vary from one solution to another.

Alexander Friedmann

FLRW Extract 3. Gravity and the cosmological constant, Λ, in the equation.

The Friedmann equations can be solved exactly in presence of a perfect fluid with equation of state

$$p = w\rho c^2,$$

where p is the pressure, ρ is the mass density of the fluid in the comoving frame and w is some constant.

In spatially flat case ($k = 0$), the solution for the scale factor is

$$a(t) = a_0\, t^{\frac{2}{3(w+1)}}$$

where a_0 is some integration constant to be fixed by the choice of initial conditions. This family of solutions labelled by w is extremely important for cosmology. For example, $w = 0$ describes a matter-dominated universe, where the pressure is negligible with respect to the mass density. From the generic solution one easily sees that in a matter-dominated universe the scale factor goes as

$$a(t) \propto t^{\frac{2}{3}} \quad \text{matter-dominated}$$

Another important example is the case of a radiation-dominated universe, namely when $w = \frac{1}{3}$. This leads to

$$a(t) \propto t^{\frac{1}{2}} \quad \text{radiation-dominated}$$

Note that this solution is not valid for domination of the cosmological constant, which corresponds to an $w = -1$. In this case the energy density is constant and the scale factor grows exponentially.

FLRW Extract 4. We see the power function in the second equation. C.f. trend-lines in our graphs.

If the matter is a mixture of two or more non-interacting fluids each with such an equation of state, then

$$\dot{\rho}_f = -3H\left(\rho_f + \frac{p_f}{c^2}\right)$$

holds separately for each such fluid f. In each case,

$$\dot{\rho}_f = -3H\left(\rho_f + w_f \rho_f\right)$$

from which we get

$$\rho_f \propto a^{-3(1+w_f)} .$$

For example, one can form a linear combination of such terms

$$\rho = Aa^{-3} + Ba^{-4} + Ca^{0}$$

where A is the density of "dust" (ordinary matter, $w = 0$) when $a = 1$; B is the density of radiation ($w = \frac{1}{3}$) when $a = 1$; and C is the density of "dark energy" ($w = -1$). One then substitutes this into

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2}$$

and solves for a as a function of time.

FLRW Extract 5. The form of the standard cosmology solution. The last two equations give a differential equation for the expansion rate, with four distinct factors.

$$(da/dt)^2 = G^*A/a + G^*B/a^2 + G^*Ca^2 - kc^2$$

$G^* = 8\pi G/3$ is constant. The four terms correspond to four different types of mass-energy.

- The first two term, *A,* is *matter (with mass).* The second term, *B,* is *radiation.*
- Their contribution to the speed of expansion reduces as the universe expands (*a* → *bigger).*
- The third term, Ca^2*, also called lambda, increases with time.*
- The last term kc^2 is a curvature that does not vary with time.

The *dark energy or lambda* term, *C,* eventually overtakes everything else. It makes the universe expand ever faster, and "explode". We commonly see this equation in terms of densities parameters and the Hubble constant.

The expansion rate is described by the time-dependent Hubble parameter, $H(t)$, defined

$$H(t) \equiv \frac{\dot{a}}{a},$$

where $\dot{a}$ is the time-derivative of the scale factor. The first Friedmann equation gives the expansion rate in terms of the matter+radiation density ρ, the curvature k, and the cosmological constant Λ,[10]

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3},$$

Lambda-CDM model
WIKIPEDIA

Lambda-CDM Extract 1. This appears to have an extra lambda-term compared to the previous, but it is combined in the density term.

Lambda-CDM model

Wikipedia
The Free Encyclopedia

Since the densities of various species scale as different powers of a, e.g. a^{-3} for matter etc.,

the Friedmann equation can be conveniently rewritten in terms of the various density parameters as

$$H(a) \equiv \frac{\dot{a}}{a} = H_0 \sqrt{(\Omega_c + \Omega_b)a^{-3} + \Omega_{\text{rad}} a^{-4} + \Omega_k a^{-2} + \Omega_{DE} a^{-3(1+w)}}$$

where w is the equation of state parameter of dark energy,

In the minimal 6-parameter Lambda-CDM model, it is assumed that curvature Ω_k is zero

and $w = -1$, so this simplifies to

$$H(a) = H_0 \sqrt{\Omega_m a^{-3} + \Omega_{\text{rad}} a^{-4} + \Omega_\Lambda}$$

Observations show that the radiation density is very small today, $\Omega_{\text{rad}} \sim 10^{-4}$;

if this term is neglected the above has an analytic solution[12]

$$a(t) = (\Omega_m / \Omega_\Lambda)^{1/3} \sinh^{2/3}(t/t_\Lambda)$$

where $t_\Lambda \equiv 2/(3H_0\sqrt{\Omega_\Lambda})$; this is fairly accurate for $a > 0.01$ or $t > 10$ million years.

Solving for $a(t) = 1$ gives the present age of the universe t_0 in terms of the other parameters.

Lambda-CDM Extract 2. The solution that all modern cosmology is based on.

Appendix 4. Note on earlier version.

Cardioid solution graph [Holster 2014/2015].

This is an equation of motion for *R'*, and it has a simple solution:

R'(t) = (R'$_{MAX}$ /2)(1-cos(π T'/T'$_{MAX}$)) Evolution equation.

Where *R'$_{MAX}$* is the maximum expansion (in true variables). This is a simple cardioid function.

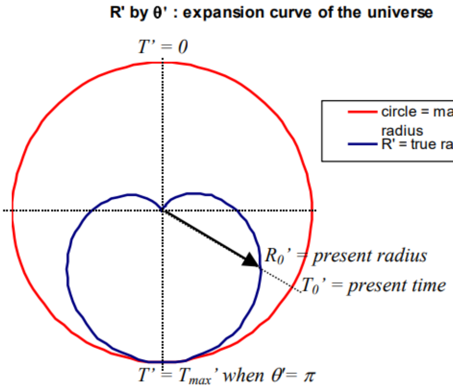


Figure 32. The cardioid solution for the universe expansion, blue. Time *T'* is the angle around the circle. The radius *R'* is a cardioid function, the length (black arrow) from the centre.

This is in *true (dashed) variables,* so must be converted to conventional variables.

The result for conventional time, *T,* is:

T = (R'$_{MAX}$/R$_0$')^2(3T'/8–sin(AT')cos(AT')/2A + sin(2AT')cos(2AT')/16A)

Figure 54. Holster 2014. The cardioid function is traditionally defined: $r = 2a(1 - \cos\theta)$ but it has the equivalent form: $r = 4a \sin^2(\theta/2)$ in half the angular variable.

Exercise. $\cos\alpha + \cos\beta = 2\cos\frac{1}{2}(\alpha+\beta)\cos\frac{1}{2}(\alpha-\beta)$ Identity.

Let $\beta = 0$. $\cos\alpha + 1 = 2\,cos^2\left(\frac{\alpha}{2}\right) = 2\left(1 - sin^2\left(\frac{\alpha}{2}\right)\right)$ Substitute.

$2\,sin^2\left(\frac{\alpha}{2}\right) = (1 - \cos\alpha)$ Rearrange.

Let: $\alpha = \left(\frac{\pi T}{T_{max}}\right)$ and multiply by $R_{max}/2$.

$$R_{max}\,sin^2\left(\frac{\pi T}{2T_{max}}\right) = \frac{R_{max}}{2}\left(1 - \cos\left(\frac{\pi T}{T_{max}}\right)\right)$$ Cardioid model.

Figure 55. WIKIPEDIA. Cardioid.

There is a substantial Wikipedia article on the cardioid, and the third equation gives its traditional definition. A number of parametric forms and geometric interpretations are given. Oddly, the sin-squared form used here is not given. It is useful in our model to view it in this form.

Equations [edit]

Let a be the common radius of the two generating circles with

- parametric representation:

$$x(\varphi) = 2a(1-\cos\varphi)\cdot\cos\varphi\,,$$
$$y(\varphi) = 2a(1-\cos\varphi)\cdot\sin\varphi\,, \qquad 0 \le \varphi < 2\pi$$

and herefrom the representation in

- polar coordinates:

$$r(\varphi) = 2a(1-\cos\varphi).$$

TAU Predictions [Holster 2014/15]

Holster 2014/15 **A Geometric Universe**

The model also provides natural mechanisms to model:

- *Quantum wave function collapse*
- *Non-local connectivity and quantum entanglement*
- *Large-scale gravitational anomalies*

The model makes some direct empirical predictions, including:

- *Predicts the measured current age: Z_0/c from $\{2, \pi, c, h, G, m_e, m_p\}$.*
- $Z_0/c = h^2/2\pi^2 m_e m_p^2 Gc = 13.823$ *billion years.*
- *Predicts the fundamental electric charge q from $\{2, \pi, c, h, m_e, m_p, \varepsilon_0\}$.*
- $q = (m_p/m_e)^{1/3}(2\varepsilon_0 hc)^{1/2}$
- *Predicts the rate of change of G from the radial expansion rate: dR'/dt'.*
- $dG/dt = 9.8\ 10^{-13}$ *parts per year.*
- *This gives the normalised rate:*
- $(dG/dt)/G = 1.4\ 10^{-11}$ *parts per year.* a bit smaller
- *(Subject to more precise determination of the expansion rate: dR'/dt').*
- *Predicts the true age of the universe is 32.0 billion years.* 55.4 By
- *Predicts structures much older than 13.8 billion years should have formed.*
- *Predicts structures have had much longer to form than conventionally thought, with stronger gravity through the early stages.*
- *Predicts the present radius of the universe is 21.7 b.l.y.* 27.5 Bly
- *Predicts the present circumference of the universe is 136.5 b.l.y.*
- *Predicts the Hubble parameter over the expansion of the universe.*
- *Predicts that the recent past expansion of the universe radius, R, will appear to be accelerating in conventional variables.*
- *Predicts small differences from GTR for solar-system scale phenomena, including 14 +/-3 seconds for the anomaly in the Pioneer space craft trajectories in 2003.*
- *Predicts conventional cosmology will generate multiple anomalies.*
- *Predicts the hypothetical substances of dark matter, dark energy, and the cosmological constant, are not real substances. They have been inferred from incomplete theories of gravity and cosmology.*
- *Predicts GTR black holes are not real.* No singularities

66

Figure 56. From [Holster 2014/15], The model here is almost identical, with parameters slightly revised.

The earlier model had an inconsistency as follows.

Correction to [Holster 2014/15].

The [Holster, 2014/2015) preprint "A Geometric Universe with Time Flow" analyses the Cardioid solution in sections 25-27. It is obtained from the fundamental theory (TAU). The solution has an incorrect factor of *2* or π in the relationship proposed in [32.1] and [32.2].

> **32. Time to maximum expansion.** **A Geometric Universe**
>
> From 26.3 and 12.4 we can obtain the time of maximum expansion as a function of the local constants alone, as:
>
> [32.1] $T'_{MAX} = \pi R_0'/c_0'$
> $= h_0^2/2\pi m_0^3 G_0 c_0$
> $= h'^2/2\pi m'^3 G' c'$
> $= \pi Z_0/c_0$
>
> This is an invariant: it does not depend on *R'* or *T'*. The value will appear to be the same value at any point in history (once the units for the variables are set at one point in history). T'_{MAX} is predicted to be:
>
> [32.2] $T'_{MAX} = \pi$ *13.823 billion years*
> *= 43.43 billion years'*

[32.1] appears to be missing a factor of 2, and [32.2] gives T_{MAX} half the value in our model.

The key quantity however, which fixes the interpretation, is the empirical value of the fundamental constants.

> **Predict *Z*.** $Z_0 = h^2/2\pi^2 m_e m_p^2 G$ = *13.823 billion l.y. (distance)*
> **Predict *Z/c*.** $Z_0/c = h^2/2\pi^2 m_e m_p^2 Gc$ = *13.823 billion years. (time)*

Z_0 should probably be defined as twice this value. Note earlier it was stated:

> **[12.4*]** $Z_0 = R_0/\pi = R_0'/2\pi$ [Interpret *Z*, match measurement to model]

But it seems [12.4*] should not have the factor of pi.

> **Predict *Z*.** $Z_0 = h^2/2\pi^2 m_e m_p^2 G$ = *13.823 billion l.y. (distance)*
> **Predict *Z/c*.** $Z_0/c = h^2/2\pi^2 m_e m_p^2 Gc$ = *13.823 billion years. (time)*

These are correct calculations of the constants.

> [26.3] $T'_{MAX} = \pi R_0'/c_0'$

We have twice this value in the present model. Getting the factors of *2* and π correct in the equations is a challenge. It is made more confusing because of coincidences in the data, including: $1/H_0^* \approx T_0^*$, $A'T' \approx 1$, $\tan(A'T') \approx \pi/2$, $H^* \approx (\pi/2) H$. It is essential to test analytic solutions with spreadsheets or numeric simulations.

Appendix 5. Counterfactual model for present time.

Counterfactual reasoning in the new model involves *reasoning about the world from a counterfactual present time.* We choose our *present time in the expansion cycle* as the key parameter, and that gives us all the predictions for our universe. Does it tell us the predictions from the point of view of another present time?

E.g. we have chosen 0.64, but let us imagine that the time is really only 0.50 through the cycle. What will the time and expansion appear like *from the point of view of someone at 0.50?* Can we tell this from our model? Well, we can work it out from our model of course. But it is hard to visualise because variables *counterfactually change their values*. In the standard theory, measurement variables do not change in this way.

This comes back to the primary feature: that *the laws of model* are time translation invariant only in the model variables, and not in the conventional variables. We can only logically derive equations in the model theory. When we transform them into the conventional variables, they are harder to visualise.

CARDIOID MODEL TAU COSMOLOGY						Empirical Age To	Empirical Radius Ro		Empirical expansion		Empirical Hubble Ho	Numeric errors	
©ATASA RESEARCH 2022.			Yellow-red cells set parameters.			13.80	13.77	0.995	67-73 (km/sec)/MPSec?		71.00		
TIME STEPS	TRUE VARIABLES: Dashed T', R', H'.			38.6400		CONVENTIONAL VARIABLES.			Hubble conversion		1.02E-12	Time Flow Rate	
Empirical NOW=(1-100)	To' | T'MAX (By)	A'To' (Radian)	Ro' | R'MAX (Bly)	dRo'/dT' (Ly/y)	Ho' (1/By)	To | TMAX (By)	Ro|RMAX (Bly)	dR/dT speed (Ly/y)	Ho (1/By)	Hubble ((km/s)/MPS)	Ho π/2 ((km/s)/MPS)	Apparent age by true age.	Rate of Time flow.
64	55.493	1.005	27.546	0.638	0.023	13.76	13.77	0.644	0.047	45.9	72.3	0.248	0.980
0.867	86.71	1.571	38.64	0.01	0.000	63.98	27.10	0.0	0.0	0.3	0.0	0.74	1.97
TMAX' = πRo'	86.5	RMAX = Vo^2Ro	38.757	TMAX = 3π/8 RMAX^2/Ro		63.855			TRUE	TRUE	MEASURED		2% error numeric
T' increments 0 - 100	T' = true time Byrs.	A'T' = (π/2)(T'/T'max)	R' = R'max sin^2(A'T')	dR'/dT' Numeric	H' = (dR'/dT')/R'	T = f(T') = conventional time Byrs.	R = R'^2/2Ro'	dR/dT (ly/y)	H = (dR/dT)/R (1/By)	H ((km/sec)/MParSec)	πH/2	T/T'	dT/dT'
64	55.49	1.01	27.55	0.64	0.02	13.762	13.8	0.644	0.047	46	72	0.248	0.980

CARDIOID MODEL TAU COSMOLOGY						Empirical Age To	Empirical Radius Ro		Empirical expansion		Empirical Hubble Ho	Numeric errors	
©ATASA RESEARCH 2022.			Yellow-red cells set parameters.			13.80	9.66	1.273	67-73 (km/sec)/MPSec?		71.00		
TIME STEPS	TRUE VARIABLES: Dashed T', R', H'.			38.6400		CONVENTIONAL VARIABLES.			Hubble conversion		1.02E-12	Time Flow Rate	
Empirical NOW=(1-100)	To' | T'MAX (By)	A'To' (Radian)	Ro' | R'MAX (Bly)	dRo'/dT' (Ly/y)	Ho' (1/By)	To | TMAX (By)	Ro|RMAX (Bly)	dR/dT speed (Ly/y)	Ho (1/By)	Hubble ((km/s)/MPS)	Ho π/2 ((km/s)/MPS)	Apparent age by true age.	Rate of Time flow.
50	43.354	0.785	19.320	0.700	0.036	9.83	9.66	0.711	0.074	72.2	72.2	0.227	0.969
0.867	86.71	1.571	38.64	0.01	0.000	130.06	38.64	0.0	0.0	0.1	0.0	1.50	4.00
TMAX' = πRo'	60.7	RMAX = Vo^2Ro	28.784	TMAX = 3π/8 RMAX^2/Ro		91.043			TRUE	TRUE	MEASURED		2% error numeric
T' increments 0 - 100	T' = true time Byrs.	A'T' = (π/2)(T'/T'max)	R' = R'max sin^2(A'T')	dR'/dT' Numeric	H' = (dR'/dT')/R'	T = f(T') = conventional time Byrs.	R = R'^2/2Ro'	dR/dT (ly/y)	H = (dR/dT)/R (1/By)	H ((km/sec)/MParSec)	πH/2	T/T'	dT/dT'
50	43.35	0.79	19.32	0.70	0.04	9.831	9.7	0.711	0.074	72	72	0.227	0.969

CARDIOID MODEL TAU COSMOLOGY						Empirical Age To	Empirical Radius Ro		Empirical expansion		Empirical Hubble Ho	Numeric errors	
©ATASA RESEARCH 2022.			Yellow-red cells set parameters.			13.80	19.32	1.273	67-73 (km/sec)/MPSec?		71.00		
TIME STEPS	TRUE VARIABLES: Dashed T', R', H'.			38.6400		CONVENTIONAL VARIABLES.			Hubble conversion		1.02E-12	Time Flow Rate	
Empirical NOW=(1-100)	To' | T'MAX (By)	A'To' (Radian)	Ro' | R'MAX (Bly)	dRo'/dT' (Ly/y)	Ho' (1/By)	To | TMAX (By)	Ro|RMAX (Bly)	dR/dT speed (Ly/y)	Ho (1/By)	Hubble ((km/s)/MPS)	Ho π/2 ((km/s)/MPS)	Apparent age by true age.	Rate of Time flow.
50	60.696	0.785	38.640	1.000	0.026	13.76	19.32	1.016	0.053	51.5	51.5	0.227	0.969
1.214	121.39	1.571	77.28	0.02	0.000	182.09	77.28	0.0	0.0	0.1	0.0	1.50	4.00
TMAX' = πRo'	121.4	RMAX = Vo^2Ro	77.267	TMAX = 3π/8 RMAX^2/Ro		182.087			TRUE	TRUE	MEASURED		2% error numeric
T' increments 0 - 100	T' = true time Byrs.	A'T' = (π/2)(T'/T'max)	R' = R'max sin^2(A'T')	dR'/dT' Numeric	H' = (dR'/dT')/R'	T = f(T') = conventional time Byrs.	R = R'^2/2Ro'	dR/dT (ly/y)	H = (dR/dT)/R (1/By)	H ((km/sec)/MParSec)	πH/2	T/T'	dT/dT'
50	60.70	0.79	38.64	1.00	0.03	13.763	19.3	1.016	0.053	52	52	0.227	0.969

Figure 57. Top. Best fit model *64*, results in this report are based on.

Figure 58. Middle. Set present time to *50*. We set the present time value to *0.50*. The *time parameter, T_{max}',* has been left unchanged, and now it predicts T_0 incorrectly as 9.83 By.

Figure 59. Bottom. Best fit model *50*. We reset the time parameter T_{max}' to get the correct measured age: *T = 13.76 By.* The *maximum R'* adjusts to maintain the (blue) relationships, and now: *R = 19.32 Bly.* The Hubble parameter reduces to: *H_0 = 51.5.*

The Hubble evolution no longer matches the data. We are constrained to the *0.64* model to get the present age and radius to match so that: *1/H = T*.

Appendix 6. Mainstream approach to modelling.

This recent preprint in *arXiv* is representative of how physicists theorise instrumentally. The authors here propose a "novel general formalism" for optimising models in the standard theory, to match empirical departures of the model from the Hubble constant. This represents "new physics" as small deviations from the standard model, with variations of "physics" allowed in the early universe. Their example is a model with a varying electron charge and fine structure constant.

This is a good example of a purely instrumentalist methodological theory, which assumes the business of modelling is to optimise a certain statistical measure of fit. They have completely overlooked any consideration of a *counterfactual model,* such as the Cardioid model.

From our point of view, this is of little if any interest. It is purely about hacking statistics, not making a real model. It does not recognise the Cardioid model as an alternative. It does not recognise any need for variable transformations between theories. The examples given of testing for variations in the electric charge or fine structure constant are theoretically nonsensical. This whole idea of *ad hoc* "theory creation" without any underlying fundamental model is anathema to our *realist* approach.

> **What it takes to solve the Hubble tension through modifications of cosmological recombination**
>
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> (Dated: December 9, 2022)
>
> We develop a novel general formalism allowing us to obtain values of the Hubble constant in agreement with late-time observables without degrading the fit to Cosmic Microwave Background data, considering perturbative modifications around a fiducial ΛCDM cosmology. Taking as proof-of-principle the case of a time-varying electron mass and fine structure constant, we demonstrate that a modified recombination *can* solve the Hubble tension and lower S_8 to match weak lensing measurements. Once baryonic acoustic oscillation and uncalibrated supernovae data are included, however, it is not possible to fully solve the tension with perturbative modifications to recombination.

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They propose a general formalism for creating and evaluating cosmological theories.

> While we focus on perturbations to recombination in this work, our formalism can be applied more generally

And they think this "phenomenological framework" should "inspire a model-building effort from the cosmology and particle physics communities".

> Conclusion We trust that the phenomenological framework we laid out, and the specific examples we provide here in terms of a modified recombination, will inspire a model-building effort from the cosmology and particle physics community with potential implications well beyond the mere study of cosmological tensions.

It is like a throw-back to C19th positivism in chemistry – which all went in the trash bin when they found the real theories in the C20th. Positivism wasted a large amount of time and energy.

But we want to ask: can it deal with the Cardioid model?

No: it provides no way to compare a *non-standard realist theory.*

They start by lauding the standard model, and its "astonishing fit" with data.

> *Introduction* — The standard Λ Cold Dark Matter (ΛCDM) model has been providing an astonishing fit to a wide variety of cosmological data. Yet, the precise value of a very basic parameter of the model, the present-time expansion rate of the Universe (or Hubble constant) H_0, remains the subject of intense debate. On

The Hubble tension is the main problem they see. They start with the assumption that the general framework of the standard model is right, and "new physics" is going to be about adjusting combinations of matter and energy, in the evolution of the universe, within "perturbations" or extensions of the standard model.

> rors as a reason for the discrepancy, it may also hint at new physics, or extensions of the ΛCDM model. To resolve this Hubble tension, an enormous number of models have been proposed. Late-time solutions, which include late dark energy, emergent dark energy, interacting dark energy, and decaying CDM, have been shown to be less effective [6–15]. This is because post-recombination solutions do not change the sound horizon at baryon decoupling, r_d, and can therefore not fit baryonic acoustic oscillation (BAO) data and uncalibrated Type Ia supernovae (SNIa) data while increasing the Hubble constant

They conclude that studies have shown that *late-time* "solutions" are "less effective", implying that "a modification in early-time cosmology is needed to solve the Hubble tension."

> (so-called "sound horizon problem"). This implies that a modification in early-time cosmology is needed to solve the Hubble tension [11, 16–19] (see also Ref. [20] for a newly proposed quantity in the context of H_0 tension: the age of the Universe, and see Ref. [21] for a study of the degeneracy of H_0 with the CMB monopole temperature T_0). Early-time solutions focus on the reduction of the sound horizon at recombination, through either an increase in energy density e.g. via early dark energy (EDE) [22–27] or additional dark radiation [28–30], or a modification of the recombination history itself by, for example, introducing primordial magnetic fields (PMF) [31–33] (see Refs. [34, 35] for whether small-scale baryon clumping due to PMF can resolve the Hubble tension together with Ref. [36] for a general formalism to estimate the effect of small-scale baryon perturbations on CMB anisotropies) or varying fundamental constants [37–40] (see also Refs. [41, 42] for non-standard recombination).

Now comes the big idea: they propose a *general formalism to drive the model choice to "*find minimal *data-driven* extensions to the LCDM model producing desired shifts in cosmological parameters… while not worsening the fit to a given data set."

In this paper, we move beyond the model-by-model approach as an effort to resolve the Hubble tension, and develop a new generic formalism to find minimal *data-driven* extensions to the ΛCDM model producing desired shifts in cosmological parameters (in this case, an increase in H_0), while not worsening the fit to a given data set. We cast this question as a well-defined simple mathematical problem. With this formalism, as examples, we extract the shape of a time-varying electron mass $m_e(z)$ or fine structure constant $\alpha(z)$ modifications that would result in a better agreement of a given early-Universe data set with SH0ES. Note that, however, we do not discuss whether the modification that we find is realistic,

This will apparently give physicists a way to propose any *ad hoc* "variations" they want, and automatically find the optimal model to fit the data. Of course this means that *the standard model will never be questioned again.* They have a concept for automating the process.

Provided that the fiducial model is sufficiently close to the observations, we can approximate $\partial\chi^2/\partial\Omega^i$ to include only the leading contribution, which then implies

$$\Omega^i_{\rm bf} \approx \Omega^i_{\rm fid} - (F^{-1})_{ij} \frac{\partial \boldsymbol{X}}{\partial \Omega^j}\Big|_{\rm fid} \cdot \boldsymbol{M}(\vec{\Omega}_{\rm fid}) \cdot (\boldsymbol{X}(\vec{\Omega}_{\rm fid}) - \boldsymbol{X}^{\rm obs}). \quad (5)$$

Inserting this solution into the Taylor-expanded chi-squared we find the approximate best-fit chi-squared

$$\chi^2(\vec{\Omega}_{\rm bf}) \approx (\boldsymbol{X}(\vec{\Omega}_{\rm fid}) - \boldsymbol{X}^{\rm obs}) \cdot \widetilde{\boldsymbol{M}} \cdot (\boldsymbol{X}(\vec{\Omega}_{\rm fid}) - \boldsymbol{X}^{\rm obs}) \quad (6)$$

where $\widetilde{\boldsymbol{M}}$ is defined as

$$\widetilde{M}_{\alpha\beta} \equiv M_{\alpha\beta} - M_{\alpha\gamma} \frac{\partial X^\gamma}{\partial \Omega^i} (F^{-1})_{ij} \frac{\partial X^\sigma}{\partial \Omega^j} M_{\sigma\beta}, \quad (7)$$

These are the primary equations of their theory. They explain how to apply them to "new physics".

Introducing new physics — Our main results so far, Equations (5) and (6), apply to an arbitrary theoretical model, provided that it gives a reasonable fit to the data for the chosen fiducial cosmological parameters $\vec{\Omega}_{\rm fid}$. The best-fit parameters and chi-squared of a new theoretical model $\boldsymbol{X}'(\vec{\Omega}) = \boldsymbol{X}(\vec{\Omega}) + \Delta\boldsymbol{X}(\vec{\Omega})$ differ from those of the standard model $\boldsymbol{X}(\vec{\Omega})$ by small amounts $\Delta\Omega^i_{\rm bf}$ and $\Delta\chi^2_{\rm bf}$, respectively. Assuming $\Delta\boldsymbol{X}(\vec{\Omega}_{\rm fid})$ and $\boldsymbol{X}(\vec{\Omega}_{\rm fid}) - \boldsymbol{X}^{\rm obs}$ are approximately of the same order of magnitude, and by writing a change in the theoretical model due to changes in a smooth function $f(z)$ as

$$\Delta\boldsymbol{X} = \int dz\, \frac{\delta \boldsymbol{X}}{\delta f(z)} \Delta f(z), \quad (8)$$

So their assumption is that the data departs from the standard model predictions (of H) by "small amounts", and their process will optimise parameters for a new model, to bring the model predictions back into line with the data.

we obtain the resulting changes in the best-fit parameters and chi-squared

$$\Delta\Omega^i_{\rm bf} = \int dz\, \frac{\delta\Omega^i_{\rm bf}}{\delta f(z)}\Delta f(z), \tag{9}$$

$$\Delta\chi^2_{\rm bf} = \int dz\, \frac{\delta\chi^2_{\rm bf}}{\delta f(z)}\Delta f(z) + \frac{1}{2}\iint dz\, dz'\, \frac{\delta^2\chi^2_{\rm bf}}{\delta f(z)\delta f(z')}\Delta f(z)\Delta f(z'), \tag{10}$$

where

$$\frac{\delta\Omega^i_{\rm bf}}{\delta f(z)} = -(F^{-1})_{ij}\frac{\partial \boldsymbol{X}}{\partial\Omega^j}\cdot \boldsymbol{M}\cdot\frac{\delta\boldsymbol{X}}{\delta f(z)}, \tag{11}$$

$$\frac{\delta\chi^2_{\rm bf}}{\partial f(z)} = 2(\boldsymbol{X}(\vec{\Omega}_{\rm fid}) - \boldsymbol{X}^{\rm obs})\cdot\widetilde{\boldsymbol{M}}\cdot\frac{\delta\boldsymbol{X}}{\delta f(z)}, \tag{12}$$

$$\frac{\delta^2\chi^2_{\rm bf}}{\delta f(z)\delta f(z')} = 2\frac{\delta\boldsymbol{X}}{\delta f(z)}\cdot\widetilde{\boldsymbol{M}}\cdot\frac{\delta\boldsymbol{X}}{\delta f(z')}, \tag{13}$$

And these equations, we are assured, become “tractable” with “simplified expressions…”.

where $F_{ij}, \boldsymbol{M}, \widetilde{\boldsymbol{M}}, \partial\boldsymbol{X}/\partial\Omega_i$ and $\delta\boldsymbol{X}/\delta f(z)$ are all to be evaluated at the fiducial cosmology and in the standard model. With the simplified expressions of Eqs. (9)–(13), the optimization problem of Eq. (1) becomes tractable. Note that Eq. (9) together with Eq. (11) has the same form as the linear bias due to ignored contribution in observables [47], systematic offset [48], or biases in fixed parameters [49] while what causes a shift in Eq. (9) is new physics $\Delta f(z)$.

So this is what *new physics* consists of: finding perturbations of functions from the standard model predictions.

While our formalism is general and could be applied to any function $f(z)$ on which observables depend, in this work we will consider modifications to the cosmological ionization history. Specifically, we will consider time-dependent relative variations of the electron mass $(f(z) = \ln m_e(z))$ in the main text, generalizing the constant change to the electron mass which has been shown to be a promising solution [38, 39, 43]. We also consider time-dependent variations of the fine structure constant $(f(z) = \ln\alpha(z))$, in Appendix. F.[2]

But these proposals, that they consider as empirical variations of the standard model of cosmology, appear as theoretically nonsensical as physics. Our approach is that we must work out the implications and predictions for a *new theory,* by reasoning *counterfactually* in the new theory. Their *instrumentalist approach* ignores the role of models and is blind to theoretical counterfactuals.

Appendix 7. Historical measures of H.

Hubble tensions: a historical statistical analysis

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Table 1. Outliers: measurements of H_0 in which $|H_0 - \overline{H_0}| > 2.8\sigma$, where $\overline{H_0}$ = 68.26 km s^{-1} Mpc^{-1} is the weighted average of the 163 values of the literature.

Year	H_0 (km s^{-1} Mpc^{-1})	$\frac{\vert H_0-\overline{H_0}\vert}{\sigma}$	Authors
1976	50.3 ± 4.3	4.2	Sandage & Tammann
1984	45.0 ± 7.0	3.3	Jõeveer
1990	52.0 ± 2.0	8.1	Sandage & Tammann
1993	47.0 ± 5.0	4.3	Sandage & Tammann
1994	85.0 ± 5.0	3.3	Lu et al.
1996	84.0 ± 4.0	3.9	Ford et al.
1996	57.0 ± 4.0	2.8	Branch et al.
1996	56.0 ± 4.0	3.1	Sandage et al.
1998	65.0 ± 1.0	3.3	Watanahe et al.
1998	44.0 ± 4.0	6.1	Impey et al.
1999	60.0 ± 2.0	4.1	Saha et al.
1999	55.0 ± 3.0	4.4	Sandage
1999	54.0 ± 5.0	2.9	Bridle et al.
1999	42.0 ± 9.0	2.9	Collier et al.
2000	65.0 ± 1.0	3.3	Wang et al.
2000	52.0 ± 5.5	3.0	Burud et al.
2004	78.0 ± 3.0	3.2	Wucknitz et al.
2006	74.9 ± 2.3	3.0	Ngeow & Kanbur
2006	74.0 ± 2.0	2.9	Sánchez et al.
2008	61.7 ± 1.2	5.7	Leith et al.
2012	74.3 ± 2.1	2.9	Freedman et al.
2013	76.0 ± 1.9	4.1	Fiorentino et al.
2016	73.2 ± 1.7	2.9	Riess et al.
2018	73.5 ± 1.7	3.1	Riess et al.
2018	73.3 ± 1.7	3.0	Follin & Knox
2018	73.2 ± 1.7	2.9	Chen et al.
2019	74.0 ± 1.4	4.1	Riess et al.

This illustrate how shaky the empirical data on the Hubble constant has been over the years. Some 20% of the sample of 163 studies of *H* are classified as outliers at more than 2.8 σ away from 68.26. There are some large sigmas and wild looking numbers in the 1990's and 2000's. Note that the two main methods using cephid variables and the CMBR converge on different values, about 73 and 68.