Chapter 26

Poles Apart

German philosopher of science Hans Reichenbach, who was one of only five students to attend Einstein's first seminar on General Relativity, wrote in 1927,

> *'Mathematical space is a **conceptual structure**, and as such ideal. Physics has the task of coordinating one of these mathematical structures to **reality**.'* [Emphasis his] [a]

In other words, all the universe may be maths but not all maths is the universe, and nearly a century on from Reichenbach's exertions the task of physics remains largely incomplete. Of the many existing models of the universe, the most widely accepted is the Friedman-Lemaître-Robertson-Walker metric (FLRW) or Big Bang model, independently developed during the 1920s and 30s by the four named authors and considered the Standard Model of modern cosmology. Although current measurements are considered insufficient to discern whether the universe deviates from flatness such that it might possess global curvature, the model allows for a hyperspherical interpretation based on the 4-Dimensions of space-time.

Earlier, in Chapter 9, I extrapolated the Flatlander's viewpoint up by two dimensions, which revealed the universe proper (inhabited by our character *Abbott*) to be, in principle at least, a 4D hypersphere. Unfortunately this doesn't really help us to visualise its shape, because we can neither see nor imagine in 4-Dimensions. Shape *per se* is therefore, I believe, the wrong way to think about it; suffice to say that the universe *may be represented mathematically* by a hypersphere. We must allow the hyperspherical 'shape' of the block universe to be whatever it is in the 4th Dimension and concentrate on how that presents itself to our view in 3-Dimensions. To access this, the question we therefore need to ask is,

'What is the relationship between the two?'

Flatland geometry shows that an inhabitant of an *n*-D universe will actually view her universe one dimension down, in (*n*-1)D. This I termed the *'Edge-On' Principle*[b] and, as I have stressed, in the real world this simple *Flatland* observation explains why we experience the world around us in 3D: it is because *the universe itself* is 4-Dimensional. We are about to take this and apply it to the behaviour of light from the origin as it arrives at us from the extreme surface of the observable universe, and by the application of basic geometrical principles embodied in EA Abbott's *Flatland* it should be possible for us to work out the 3-Dimensional shape of the observable universe.

This may sound rather lofty and far-fetched, but I assure you it is not. In this chapter I will describe a model of the universe as a hypersphere having the property that it is divided mathematically into two 'halves', corresponding – up by one dimension – to the northern and southern hemispheres of a globe. Happily this is not entirely restricted to mathematics because we can access it visually by using the analogy of the globe of the Earth. In this we are in good company as Professor Frank Close of Oxford University counsels us to…

> *'Recall that Einstein's original inspiration came from the two-dimensional surface of the Earth, which is curved in a third dimension.'* [c]

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[a] Hans Reichenbach, *The Philosophy of Space and Time*, Dover 1957, P287

[b] *The 'Edge-On' Principle:* Each dimension is viewed from within itself one dimension lower.

[c] Frank Close, *Nothing: A Very Short Introduction*, Oxford 2009, P84

Our starting premise is that light has set out radially in all directions from all points on the 3D surface of the hypersphere (i.e. everywhere). In practice, the CMB set out uniformly from *virtually* every point in the universe 380,000 years *after* the origin, at the 'surface of last scattering', and our current position in relation to it (as a fellow object) has in fact moved very slightly over deep time. However, as the release of the CMB was, like the Big Bang singularity itself, an everywhere-event, for our purposes we will treat this as a technicality and extrapolate theoretically right back into the origin in relation to which the observer has not moved[a].

CMB Rabbits

Imagine for a moment that you were invited by the architects to go check out some fine new municipal building which has just been completed, but on the way (because they wanted to show off) were asked to put on virtual reality specs which demonstrate the building in all its various states of planning and construction, and, as you step inside, you trip over imaginary long-gone rabbits in imaginary long-gone fields – which are real to you. So it is with distant, early galaxies – they're real to us, but they're long-gone, and they are not the shape of the building. Into this category falls the cosmic microwave-background (CMB). It is a field of rabbits.

We view the distant universe through virtual reality specs which show it, not as it is, but as it was when it started out, because we are still seeing the original photons. And the farther into space we look, the less accurate our picture, because our view gets increasingly fogged up by 'out-of-dateness' to the point where the things we are seeing are pretty much irrelevant to the 'current' state of things.

Of course astronomers take all this into account, but the fact remains that what we observe – captivating though the pictures are – is *billions of years wrong*. So, although we may become experts on how the farthest reaches of the universe *were*, how they actually are now remains an assumption based on the Cosmological Principle which is accepted by cosmologists, as Hawking reminds us, solely on grounds of modesty. [b]

So what does the distant universe look like *now?* Sadly it's an absolute certainty that this can never, ever be confirmed by observation or experiment. Why? Because light is just too slow… it creeps around at 300,000 km/s in the endless vastness, scratching its proverbial head and wondering if the path it is on actually leads anywhere. So, if science is ever to come to any conclusions, these will *have* to rely on the application of mathematical principles to what is already known. Because of this, what I am about to describe is not mere speculation, but a model of the universe which I believe not only fits with observation, but may explain several phenomena which are currently regarded as anomalies (chief among them dark energy).

And, perhaps most surprisingly of all, the model puts an unequivocal end to the multiverse. (Or at least any *need* for it as an explanatory tool.).

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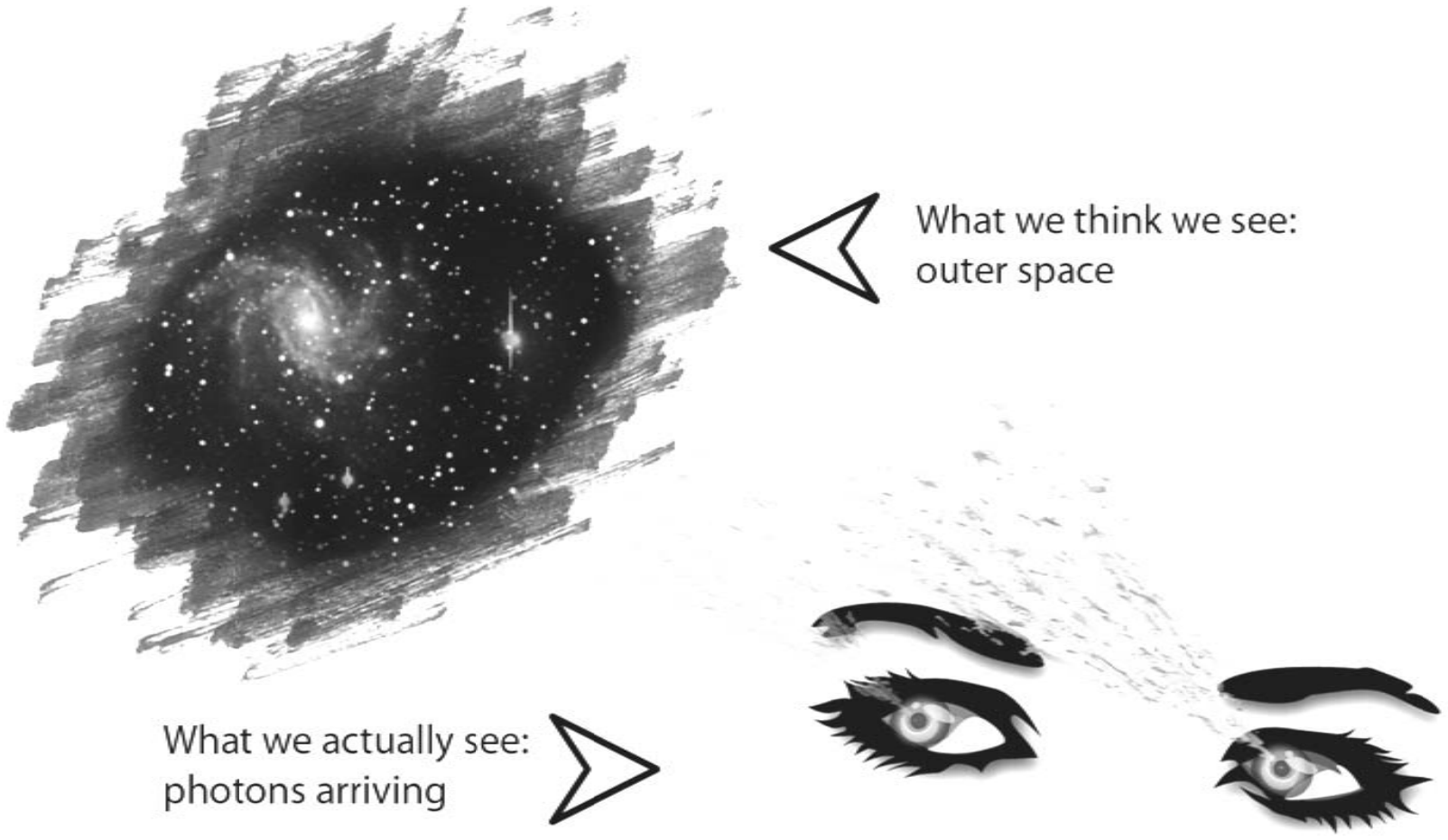
[a] Except, as we shall soon uncover, in terms of '*Centre A/B* recession'.

[b] Although, as we saw earlier in Chapter 10, it is possible to derive the principle simply by extrapolating the geometry of *Flatland*. But physicists don't like to rely *exclusively* on maths, even where direct observation will remain forever impossible.

But we start off with a problem, (although at first sight it might not even occur to us that it is a problem), which is this: *no-one can see anything out there at all*. Yes, it's true… we gaze out into space, and all we see is tiny pieces of light at zero distance hitting our retinas, lenses and spectrographs.



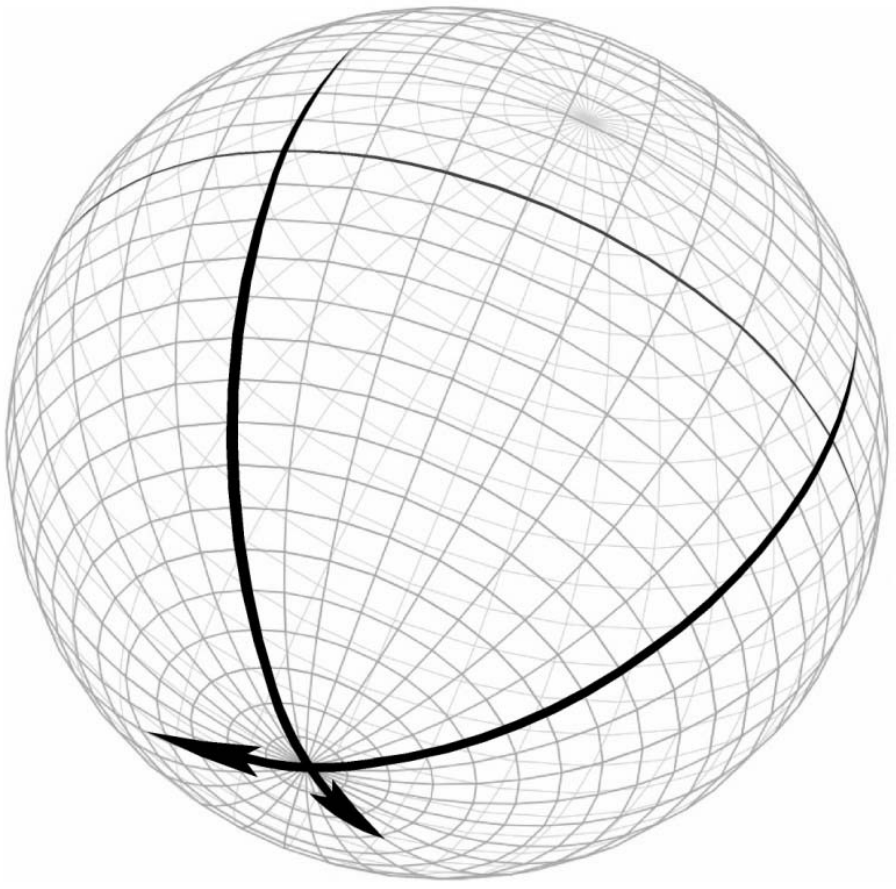
So the universe is not actually *observable* at all, it is *deducible* by our brains from photons. Of course, this is just as true in daily life as it is in astronomy, but the time delay as I look at that door over there is negligible enough to fool me into believing that I can actually 'see' across the room, which I can't, or in the case of a lab experiment to convince me that I have performed what I fondly call an observation. Essentially all I really get are photons reconstituted as slightly delayed brain signals, which approximate closely (I think[a]) to what is still out there, from which I *deduce* my surroundings. This is fine for all practical purposes because light is fast, but it doesn't translate to outer space because it's too far away, and brain signals from space approximate terribly to what is currently out there.

So – whether by radio waves, microwaves, infra-red, visible light, ultra-violet, x-rays or gamma radiation – if what we observe is history and gone forever, what do our observations and measurements actually represent? It all comes down to two things:

1) The properties of the light, and
2) The path of the light.

[a] Our brains interpret certain wavelengths from the visible spectrum, but across the animal kingdom a whole range of visual experiences are known to occur. Who is right? We imagine that what we see is how the world 'really looks' just because most humans are in agreement, but human sophistication may simply have lulled us into placing an inflated value on the wavelengths *our* brains interpret.

The first of these is well understood as astronomers study the spectra from distant light sources, and a great deal of information is gleaned. However the second has, in my opinion, been rather taken for granted[a].



The Globe Analogy

So, a small number of the primeval photons hit our receptors whilst the rest of the CMB flies around out there in straight lines[b] in all possible directions away from every point in the hypersphere, which takes us back to our question from earlier, *'How can light from the beginning still be reaching us – wouldn't it have overtaken the Earth long ago?'* This is kind of a sub-question; to get at the heart of the matter what we really need to ask is,

'What is the nature of the path that relic radiation is on?'

As we have seen, *Flatland* principles indicate that the physical universe exists as the 3D surface of a 4D hypersphere[c]. Therefore, to answer this it will be helpful to use an analogy, shifted down by one dimension, picturing the 4D universe as a 3D sphere[d] like the globe of the Earth. (This is similar, though not identical, to what Stephen Hawking did in Chapter 8 of *A Brief History of Time*.)

On this globe I now visualise the Big Bang as having occurred at the north pole, with myself as observer standing at the south pole. The light's path follows the globe's 2-Dimensional surface, radiating out in all directions from the north pole and crossing the equator. When the beams arrive at me at the south pole they just criss-cross each other and keep going. In this scenario light beams follow the lines of longitude, tracing out great circles (geodesics) all around the globe.

***3D sphere with 2D surface**:*

Now, *beginning with the analogy* let's carefully describe the situation, breaking it down into a series of simple geometrical statements which we hold to be true. On the globe's surface the following things take place:

1) Light sets off, travelling out in every 2D direction from its origin at the north pole.
2) It radiates out along lines of longitude to arrive at me.
3) I stand at the opposite pole (or antipode) from the light's origin.
4) The light crosses the 1D equator, where beams which left in opposite directions reach their maximum distance apart (the diameter of the globe).
5) At the south pole, I see the light coming at me from every direction along the flat surface of the globe.

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[a] Recent developments in gravitational lensing are divulging exciting new insights, however these are (in cosmic terms) localised phenomena.

[b] In reality there are factors which disturb this evenness, such as gravitational lensing and the Shapiro delay effect.

[c] Mathematically the 3-sphere surface of a 4-ball, although physicists might describe it as the 3D surface of a *hypersphere.*

[d] Mathematically the 2-sphere surface of a 3-ball, although physicists might describe it as the 2D surface of a *sphere.*

6) I do not see its origin at the north pole, I only see it coming at me from the equator.
7) Every light beam zones in and crosses over at me.
8) After the crossover each light beam continues on its path which, instead of shining away from its origin, now heads back toward its origin.
9) The light beams re-cross the equator and criss-cross at the north pole, repeating the journey.

4D hypersphere with 3D surface*:*

Now, shifting up to the *actual universe* by applying our *Flatland*-derived *Principle of Relationship*[a] let's replicate (extrapolate) each statement to describe what takes place one dimension higher:

1) Light sets off, travelling away from the Big Bang in every direction from every point of origin.
2) It radiates out (like light from the sun) in every 3D direction away from each origin, travelling across the universe's 3D surface (i.e. through all the 3-Dimensionality) to arrive at me.
3) I, as observer, stand at a single point which is (hyperspherically) polar opposite *one* of the myriad single points of origin from which light left. [b]
4) On its journey to me (which takes the lifetime of the universe) the light crosses the universe's 2-Dimensional 'equator' at which each beam is a maximum possible distance apart from its diametrically (in 3D) opposite beam.
5) Because I, as observer, stand at the opposite ('south') pole in 4-Dimensions on the 3D surface of the hypersphere, the light comes at me radially in 3D, shining in upon me like 'reversed sunshine'.
6) I do not see its singular origin at an antipodean 'north pole', I only see it coming at me from the equator. This is why I experience the CMB coming from every direction: it is zoning in on me from the universe's 2D equator through the 3D surface of the hypersphere. (We'll get our heads round this in a minute.)
7) As observer, I stand at the crossover (the 4D 'south pole') and any light beams coming at me *from opposite sides* will criss-cross at me and head off in opposite directions.
8) In theory they are on a path which will eventually re-cross the universe's equator at antipodean points, at which they will again be a maximum possible distance apart.
9) Circumnavigating the hypersphere, each light beam is now theoretically[c] heading back toward it's 'north pole' origin from the opposite direction in 3D from which it left.

So we see that, by applying the 3D globe analogy to our 4D reality, it explains why relic light from the CMB approaches the observer equally from every direction in space, and yet displays '*extraordinarily uniform'* (Penrose[d]) smoothness and homogeneity. The analogy tells us this is because:

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[a] *The Principle of Relationship:* Whatever is true of the relationship between two adjacent dimensions is true of the relationship between *any* two adjacent dimensions.

[b] Light left from every point in the universe, although the only one that concerns me as observer is the point from which I currently view light beams arriving. Of course the light also left from the point I now occupy, but I cannot now see that light because it is on the other side of the hypersphere.

[c] I say 'theoretically' heading back because we will shortly see that relic radiation may only ever travel a 'half-circumference'.

[d] Roger Penrose, *Cycles of Time*, Vintage 2011, P75

It's all the same light, in the sense that all the photons left from the same location at the same time[a]. They are all meeting up like long lost friends after 14 billion years. Each photon has traced its own great circle (which it experiences as a straight line) around the 3-Dimensional surface of the hyperspherical universe, reached me, then (theoretically) headed off back in the opposite direction.

Of course these are not actual poles, in the Earth sense[b]. Instead they are observer's viewpoint-based *3D antipodes* which reveal, in cross-section, a snapshot of the universe's 4-Dimensional shape and size. In light terms, this carries the highly significant implication that ***the observer is always located at a point which is polar opposite in 4-Dimensions to a point at which the universe originated***. The observer's location is an antipode (diametrically opposite point) on the surface of the hypersphere to a point of origin within the Big Bang singularity. 3-Dimensional lines of longitude on the 4-Dimensional globe (or to give it its proper name, glome) cross over at the observer.

This geometry works as an explanation of the way relic radiation is observed by astronomers to behave, and is strong evidence of a *Flatland*-style dimensional relationship between the observable universe (3D) and the universe proper (4D).

The Bitter Grapefruit

One of the issues that astronomers wrestle over is how this ancient light of the CMB that streams in from opposite sides of the sky appears so uniform, yet the sides of the sky are too far apart for light ever to have had enough time to make the journey all the way across from one side to the other. Nick Strobel at *AstronomyNotes.com* explains the situation,

> *'The photons from the microwave background have been traveling nearly the age of the universe to reach us right now. Those photons have certainly not had the time to travel across the entire universe to the regions in the opposite direction from which they came. Yet when astronomers look in the opposite directions, they see that the microwave background looks the same to very high precision.'* [c]

Theoretical physicist Matt Strassler poses the question,

> *'…how did parts that are so incredibly distant from one another end up with the same temperature to one part in 100,000?'* [d]

Because, as Stephen Hawking tells us,

> *'In the hot big bang model… there was not enough time in the early universe for heat to have flowed from one region to another. This means that the initial state of the universe would have to have had exactly the same temperature everywhere in order to account for the fact that the microwave background has the same temperature in every direction we look.'* [e]

Indeed, (Nick Strobel again),

> *Running the expansion backward, astronomers find that regions even a degree apart in angular separation on our sky would have been beyond each other's horizons at the time the microwave background was produced.'* [f]

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[a] And William of Ockham, having shaved meticulously, is throwing a party!
[b] I.e. pertaining to an axis of spin.
[c] http://www.astronomynotes.com/cosmolgy/s12.htm - Accessed 25th July 2016
[d] http://profmattstrassler.com/2014/03/21/did-the-universe-begin-with-a-singularity - Accessed 17th May 2016
[e] Stephen Hawking, *A Brief History of Time*, Bantam Books 1995, P140
[f] http://www.astronomynotes.com/cosmolgy/s12.htm - Accessed 25th July 2016

And finally Alan Guth,

> *'To explain, for example, how the universe could have smoothed itself out to achieve the uniformity of temperature we observe today in the cosmic background radiation, one finds that in the context of the standard Big Bang theory it would be necessary for energy and information to be transmitted across the universe at about a hundred times the speed of light.'* [a]

Clearly even light cannot exceed the speed of light, however, it is clear to astronomers that these two extremes – the opposite sides of the sky – *must* at one time have been in causal contact. This is called the *Horizon Problem* and it's a serious enigma which has been held up as a flaw in the model. Various ideas have been put forward to account for it, the most widely accepted of these being the Inflationary theory of the universe originated in 1980 by Alan Guth of MIT. Hawking again,

> *'According to Guth, the radius of the universe increased by a million million million million million (1 with thirty zeros after it) times in only a tiny fraction of a second.'* [b]

The thing to notice is that this was a sudden burst. The early universe was grooving along happily up to 10^{-38} seconds then… ***Voom!*** … before normal service was resumed around 10^{-36}.

But whilst Inflation has been largely accepted by the mainstream (reluctantly by some – Paul Steinhardt of Princeton for example – because it rests on infinity and leads to the multiverse), it throws up a glaring quandary: it is an event – the 'grapefruit-sized' Inflationary epoch lasting a fraction of a second – which had *a beginning* and *an end*, and no definitive cause can be found to account for either. In that sense it smacks of a 'rescue package'; an 'epicycles of Ptolemy'-style arbitrary fix of which William of Ockham would probably not have approved. Guth himself describes it as an *'add-on'*[c], and his colleague at MIT, Max Tegmark, shows particular perturbations,

> *'I have to confess that, although this process doesn't violate the laws of physics, it makes me nervous. I just can't shake the uneasy feeling that I'm living in a Ponzi scheme of cosmic proportions.'* [d]

This is the natural outcome of a scenario that was *contrived to force the two sides of the sky into subluminal contact* instead of simply accepting that they were both emitted at lightspeed from the same source[e]. The model I begin to describe above, which explains relic radiation as an observer-centric phenomenon, presents us with a universe that is far more elegant and straightforward, and – quite wonderfully – neither infinite nor arbitrary.

But...

One might ask, *'Why should the light wait until it reaches little ol' me before heading back?'*

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[a] Alan Guth, *The Inflationary Universe*, from *The Universe*, Edited by John Brockman, Harper Perennial 2014, P24
[b] Stephen Hawking, *A Brief History of Time*, Bantam Books 1995, P141
[c] Alan Guth, *A Golden Age of Cosmology*, from *The Universe*, Edited by John Brockman, Harper Perennial 2014, P2
[d] Max Tegmark, *Our Mathematical Universe*, Penguin 2015, P105
[e] Which is not to say that the universe hasn't in some way inflated – the theory has a relation to other phenomena such as galaxy-seeding fluctuations and the matter/antimatter imbalance – only that it is not required to have performed astrobatics to explain the uniformity of the CMB.

Our Earth-based concept of an equator is of a 1D line around our globe which is fixed relative to the north and south poles[a], but this is simply a ‘dropped down’ analogy in which the poles are better thought of as antipodes. The universe proper is represented by a hypersphere, so all this is a description of what happens *from an observer’s viewpoint*, who, in 4-Dimensions, may be located at any point-event. As we saw earlier, *‘little ol’ me’* is the observer, and as such occupying ‘a centre’ of the universe, which may be anywhere[b]. The universe has not the luxury of a ‘Newtonian-style’ backdrop, therefore, as with Relativity, everything depends on the observer’s frame of reference.

So we see that the globe analogy provides an explanation for:

1) The omni-directionality of the CMB, and
2) The smooth homogeneity of the CMB.

This is potentially powerful stuff, but what exactly is a 2-Dimensional equator?

[a] The observer is located, not at a ‘pole’ as such, but at an arbitrary point with an antipode, relative to which a theoretical ‘equator’ runs around midway between them.

[b] Every point-event – space-time event (x,y,z,t) – may be considered a centre, or the location of an ‘observer’.