

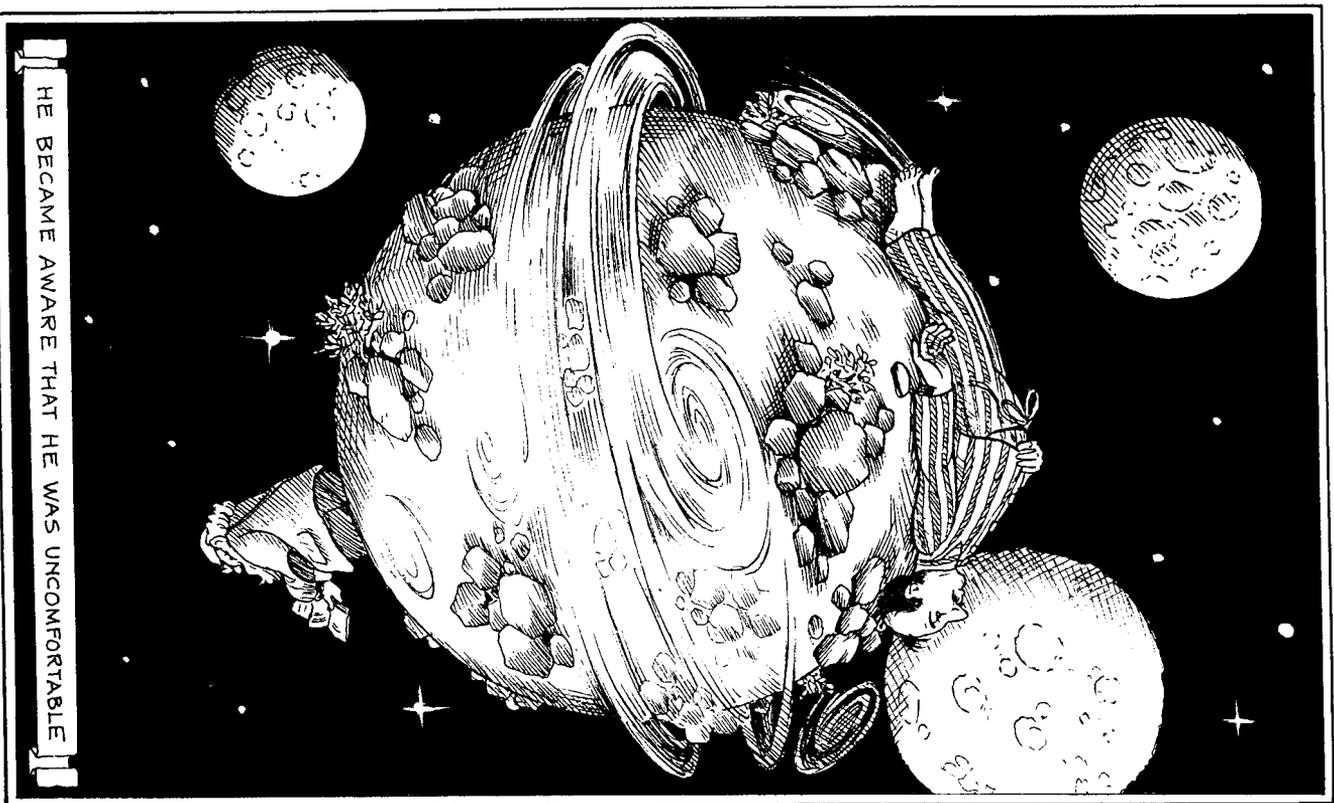
5 Mr Tompkins Visits a Closed Universe



That evening in the Beach Hotel, the professor and his daughter were deep in conversation. They talked freely of both cosmology and art. Mr Tompkins joined in from time to time as best he could, but for the most part was happy just to observe and listen. He was fascinated by Maud; he had never met anyone like her. But in due course he became sleepy and made his excuses. Climbing the stairs and reaching his room, he quickly changed into his pyjamas and collapsed on to the bed, pulling the blanket over his head. His tired brain was all mixed up.

As he lay there, one thought kept recurring. The type of cosmology that really intrigued him was that of a closed Universe – the one where if you go off from the North Pole in a straight line you will end up at the South Pole. At least it would be a Universe with a finite volume (he simply could not get his mind round the infinite volume of an open Universe). Fair enough, the professor seemed to have his reasons for thinking that the density of matter had the critical value, and so you would not be able to make that odd type of journey, and the expansion would not give way to a contraction and a Big Crunch. But what if he were wrong? What if there was a lot more dark matter out there than they had yet accounted for? What if ...?

These thoughts were interrupted as he became aware that he was uncomfortable. He had the strange feeling that instead of lying on a comfy spring mattress he was stretched out on something hard. He pulled back the blankets and peeped out. To his astonishment



HE BECAME AWARE THAT HE WAS UNCOMFORTABLE

he found himself lying on a slab of rock out in the open. The hotel had vanished!

The rock was covered with some green moss, and in a few places little bushes were growing from cracks in the stone. The space above him was illuminated by some glimmering light and was very dusty. In fact, there was more dust in the air than he had ever seen, even in the films representing dust storms in the American mid-west. He tied his handkerchief round his nose to keep from breathing the dust.

But there were more dangerous things than the dust in the surrounding space. Occasionally stones, the size of his head and larger, came whirling through space, hitting the ground around him. He also noticed one or two rocks, about 10 metres across he judged, floating through space at some distance away.

Another strange thing was that there appeared to be no distant horizon – despite his being perched high up. He decided he had better explore his surroundings. So it was he began crawling over the surface. Because the rock curved down quite sharply, he held on grimly to the protruding edges in constant fear of falling off. But then he gradually became aware of something odd; although he had moved down onto a very steep part of the rocky face – so steep he could now no longer see the blanket he had left behind, he did not feel any tendency to fall; he was still being pulled securely onto the surface. Emboldened, he continued crawling. Eventually he reckoned he must have gone through about 180° – in other words he ought to be directly *underneath* his starting point – and still there was no tendency to fall off into the surrounding dusty depths of space. He was presumably now upside-down compared with when he started out. It was then it dawned on him that the rock he was on had no visible means of support. It was a planet! A tiny planet similar to the floating rocks he had seen.

To his great surprise and relief it was at that moment he almost bumped into the legs of a familiar figure. It was the professor. He was standing there busily noting down observations in a note-book.

'Oh, it's you,' observed the professor casually. 'What are you doing down there? Lost something?'

Mr Tompkins sheepishly let go of his hand-hold, and gingerly stood up. To his great relief, not only did he not fall off into space, he did not even feel as though he would drift off into space. He began to understand what was going on. He remembered that he was taught in his schooldays that the Earth is a big round rock moving freely in space around the Sun. Everything is pulled towards its centre, so there is no danger of 'falling off', no matter where you are positioned on its surface. Now he was gently but firmly being pulled towards the centre of this new 'planet' – a planet so tiny its population numbered two.

'Good evening,' said Mr Tompkins, 'What a relief to see you.'

The professor raised his eyes from his note-book. 'There are no evenings here,' he said. 'There is no Sun', and with that he returned again to his note-book.

Mr Tompkins felt uneasy, to meet the only living person in the whole Universe, and to find him so preoccupied! Unexpectedly, one of the little meteorites came to his help. With a crashing sound, the stone hit the book in the hands of the professor and knocked it hard. It flew up into space away from their little planet. 'Oh dear,' said Mr Tompkins, 'I hope that wasn't important. I don't reckon our gravity is strong enough to pull it back.' As they watched, the book continued its journey into the furthest depths of space, getting smaller and smaller.

'Not to worry,' replied the professor. 'You see, the space in which we are now is not infinite in its extension. Oh I know that you were doubtless taught in school that space is infinite, and that two parallel lines never meet. This, however, is not true for the space of this particular Universe – the one we are now in. Our normal Universe is, of course, very large indeed; about 100,000,000,000,000,000,000 kilometres across at present, which for most purposes is fairly infinite. If I had lost my book there, it would have taken an incredibly long time to come back – even assuming it were a Universe of the closed type that this one is. Here, however, the situation is rather different. Just before the note-book was torn out of my hands, I had figured out that this space is only about five miles in diameter, though it is expanding. I expect the book back in not more than half an hour.'

'Are you saying that the book is going to do one of those round trip journeys in a straight line,' ventured Mr Tompkins. 'Like the one you said about taking off from the North Pole ...'

'... and landing back at the South Pole? Yes,' replied the professor. 'Precisely. The same thing is going to happen to my book – unless it's hit on its way by some other stone and gets deflected from the straight track.'

'And this has nothing to do with the gravity of our little planet pulling it back?'

'No, nothing at all to do with that. As far as the gravity here is concerned, the book has escaped into space. Here, take these binoculars, and see if you can still see it.'

Mr Tompkins put the binoculars to his eyes, and through the dust which somewhat obscured the whole picture, he managed to see the professor's note-book travelling through space far, far away. He was somewhat surprised by the pink colouring of all the objects, including the book, at that distance. Not only that, 'Your book is returning already,' he cried out excitedly. 'Yes, yes, it's definitely growing larger now.'

'No, no,' said the professor, 'it'll still be going away. Here, give those to me. He took back the binoculars, and looked intently. 'No, as I said, it's still going away. The fact that it appears to be growing in size – *as if* it were coming back – that's due to a peculiar focussing effect on the rays of light due to the closed, spherical nature of the space.'

He lowered the binoculars and scratched his greying head. 'How can I put it ...? Yes. Suppose we were back on Earth, and let's imagine that horizontal rays of light (aimed at the horizon) could be kept going all the time hugging the curved surface of the Earth (say, by refraction of the atmosphere). Under those circumstances, if an athlete were to run away from us, it wouldn't matter how far she went, we would be able, using powerful binoculars, to see her all the time during her journey. Now, if you think about the globe, you will see that the straightest lines on its surface, the meridians, first diverge from one pole, but, after passing the equator, begin to converge towards the opposite pole. If the rays of light travelled along the meridians, you, located for

example at one pole, would see the person going away from you growing smaller and smaller until she crossed the equator. After this point you would see her growing larger; it would seem to you that she was returning, albeit going backwards. Once she reached the opposite pole, you would see her as large as if she were standing right by your side. You would not be able to touch her, of course, just as you cannot touch the image formed by a spherical mirror.

'Right now,' the professor continued, 'this behaviour of light as it travels over the two-dimensional curved surface of the Earth can be used as an analogy for how light rays behave in this strangely curved three-dimensional space we find ourselves in. In fact I do believe the image of the book is about to arrive.'

As he said that, the image of the book appeared to be only a few yards away, and coming closer. It was big enough now for one no longer to need the binoculars to see it by. However, it looked rather odd; the contours were not sharp, but seemed washed out, and the writing on the cover could hardly be recognized; the whole book looked like a photograph taken out of focus and underdeveloped.

'You can see now it's only an image – not the real thing,' said the professor. 'See how its badly distorted by the light having had to travel halfway across the Universe. And notice how you can see other little planets behind the book – through its pages.'

Mr Tompkins reached out and tried to grab the 'book' as it sped passed, but his hand simply passed through the image without encountering any resistance.

'No, no,' admonished the professor. 'The book itself is now very close to the *opposite* pole of the Universe. As I've said, what you see here is just an image – in fact two images of it. The second image is just behind you and when both images momentarily coincided just then, that was when the real book was exactly at the opposite pole.'

Mr Tompkins didn't hear; he was too deeply absorbed in his thoughts, trying to remember how the images of objects are formed in elementary optics by concave and convex mirrors and lenses. When he finally gave up, the two images were receding in opposite directions.

'And all these strange effects are due to the matter in the Universe?' he eventually asked.

'That's right. The matter we're standing on – our tiny planet – curves the space in our immediate vicinity, and it is this that is responsible for the way we are held onto its surface. But more than that, the gravity of this planet combines with that of all the other masses in the Universe to produce the overall curvature that gives rise to these lensing effects. In fact, in general relativity one dispenses altogether with talk of gravitational 'forces' as such, and simply thinks in terms of curvature.'

'But tell me, if there were no matter, would we have the kind of geometry I was taught at school, and would parallel lines never meet?'

'That's right,' answered the professor, 'but neither would there be any material creature to check it.'

In the meantime, the image of the book went off again far away in the original direction, and started coming back for the second time. Now it was still more damaged than before, and could hardly be recognized at all, which, according to the professor, was due to the fact that this time the light rays had travelled round the whole Universe.

'And if we pop round to the other side of our planet ...' he added, grabbing Mr Tompkins by the arm and marching him the few yards it took to get to the other side. 'There,' he declared, pointing in the opposite direction. 'There. Can you see? Here comes my book. It's about to complete its journey round the Universe.' With a triumphant grin, he stretched out his hand, caught the book, and pushed it into his pocket. 'The trouble with this Universe is that there is so much dust and stones around, it makes it almost impossible to see round the world. Notice these shapeless shadows around us? Most probably they're the images of ourselves, and surrounding objects. It's just that they're so distorted by dust and irregularities of the curvature of space that I cannot even tell which is which.'

'Does the same effect occur in our normal Universe – the one we used to live in?' asked Mr Tompkins.

'Probably not – not if we're right about the density being critical. But,' the professor added with a twinkle in his eye.

'you have to admit, it's still fun to think this kind of thing through, don't you agree?'

By now the sky had considerably changed. There seemed to be less dust about, so Mr Tompkins was able to take off the handkerchief from around his face. The small stones were passing much less frequently and hitting the surface of their planet with much less energy. Not only that, but the other planets had drifted much farther away by now and could hardly be seen at this distance.

'Well, I must say life is getting a lot less scary,' he commented. 'Though I must say it's become quite chilly.' He picked up the blanket and wrapped it round him. 'Can you explain the change in our surroundings?' he asked, turning to the professor.

'Very easily; our little Universe is expanding and since we have been here its radius has increased from five to about a hundred miles. As soon as I found myself here, I noticed this expansion from the red- dening of the distant objects.'

'Ah, I did notice everything was pink at great distances,' said Mr Tompkins, 'but why does that signify expansion?'

'Oh that's not difficult to see,' said the professor. 'I take it you've noticed that the siren of an approaching ambulance sounds very high, but after the ambulance passes you, the tone is considerably lower? This is the so-called Doppler Effect: the dependence of the pitch (or frequency of the sound) on the velocity of the source. When the whole of space is expanding, every object located in it moves away with a velocity proportional to its distance from the observer. Therefore, the light emitted by such objects is of lower frequency, which in optics corresponds to redder light. The more distant the object is, the faster it moves and the redder it seems to us. In our normal Universe, which is also expanding, this red- dening, or the *cosmological red-shift* as we call it, permits astronomers to estimate the distances of the very remote galaxies. For example, one of the nearest galaxies, the Andromeda galaxy, shows a 0.05% redden- ing; this corresponds to the distance which can be covered by light in eight hundred thousand years. But there are also galaxies just on the limit of present telescopic power which show a reddening of about

500%, corresponding to distances of approximately ten thousand mil- lion light years (a 'light year' being – as the name implies – the distance travelled by light in one year). Such light was emitted when the Uni- verse was less than a fifth its present size. The present rate of expansion is about 0.000,000,01% per year. Our little Universe here grows com- paratively much faster, gaining in size by about 1% per minute.'

'Will the expansion of this Universe here ever stop?' asked Mr Tompkins.

'Of course it will,' said the professor. 'I told you in one of the lec- tures that a closed Universe like this one would entail the expansion eventually coming to a halt, this then being followed by the contrac- tion phase. For a Universe this small the expansion phase should, I reckon, last no more than a couple of hours.'

'A couple of hours,' echoed Mr Tompkins. 'But that would mean there can't be long to go before ...' His voice trailed off as the implica- tion sank in.

'Yes,' murmured the professor. 'I think we are now observing the state of largest expansion. That's why it's become so cold.'

In fact, the thermal radiation filling up the Universe, and now distributed over a very large volume, was giving only very little heat to their planet; the temperature was at about freezing-point.

'It's lucky for us that there was originally enough radiation to give some heat even at this stage of expansion,' the professor added. 'Otherwise it might become so cold that the air around our rock would condense into liquid and we would freeze to death.'

He peered intently through his binoculars once more. 'Ah, yes,' he said after a while. 'The contraction has already begun. It'll soon be warm again.'

He offered the binoculars to Mr Tompkins, who took them and scanned the heavens. He noticed that all the distant objects had changed their colour from pink to blue. This, according to the profes- sor, was due to the fact that all the stellar bodies had started moving towards them. He also remembered the analogy given by the professor of the high pitch of the whistle of an approaching train.

Rubbing himself to get warm, he commented, 'Well, I'll be glad when it heats up again.' But then a thought struck him. He turned anxiously to the professor. 'If everything is contracting now, shouldn't we expect that soon all the big rocks filling the Universe will come together and that we shall be crushed between them?'

'I wondered how long it would take you to work that out,' answered the professor calmly. 'But not to worry. Just think: well before that happens, the temperature will rise so high that we shall be vapourised! I suggest you just lie down and observe as long as you can.'

'Oh my!' moaned Mr Tompkins. 'I am beginning to feel hot already, even in my pyjamas.'

It was not long before the hot air became unbearable. The dust, which became very dense now, was accumulating around him, and he felt as if he were being choked. He struggled to free himself from the blanket, when suddenly his head emerged into cool air. He swallowed a deep breath.

'What's happening?' he called out to the professor – only to discover that his companion was no longer with him. Instead, in the dim light of morning, he recognised the hotel bedroom. Sighing with relief he disengaged himself from his blanket; it had become entangled after what must have been a very restless night.

'Thank God we're still expanding!' he muttered, as he made his way to the bathroom. 'That's what you might call a close shave,' he thought as he reached for the razor.

