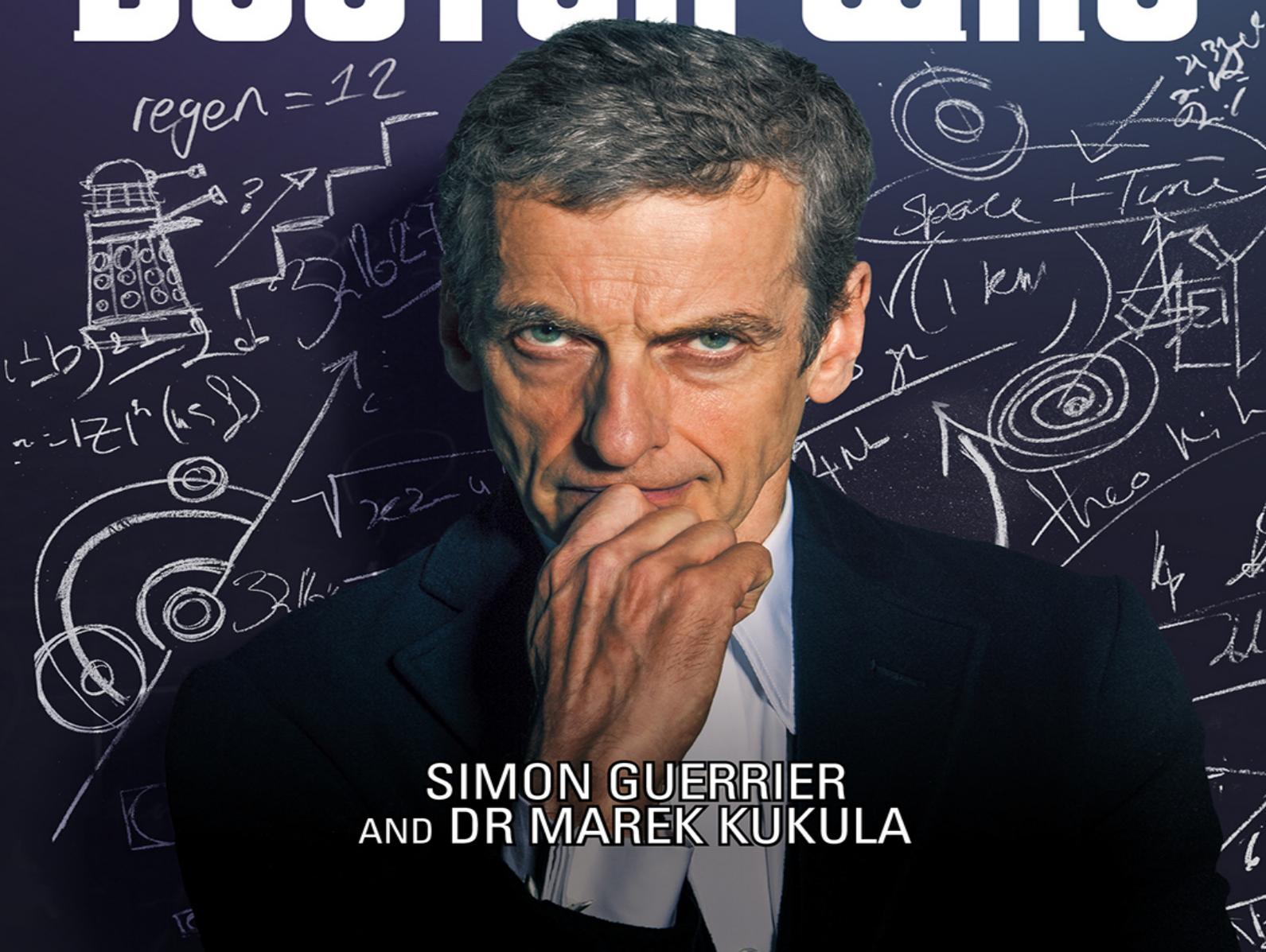


$\frac{1}{3}$ $XII \geq M$ or $\Omega??$ $\epsilon(a+b)$ 25%  $\delta^3 \sum x^2$ $\sqrt{64}$

BBC

DOCTOR WHO



**SIMON GUERRIER
AND DR MAREK KUKULA**

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ABOUT THE BOOK

The Scientific Secrets of Doctor Who is a mind-bending blend of story and science that will help you see *Doctor Who* in a whole new light, weaving together a series of all-new adventures, featuring every incarnation of the Doctor.

With commentary that explores the possibilities of time travel, life on other planets, artificial intelligence, parallel universes and more, Simon Guerrier and Dr Marek Kukula show how *Doctor Who* uses science to inform its unique style of storytelling - and just how close it has often come to predicting future scientific discoveries.

This book is your chance to be the Doctor's companion and explore what's out there. It will make you laugh, and think, and see the world around you differently.

ABOUT THE AUTHORS

Simon Guerrier has written countless *Doctor Who* books, comics, audio plays and documentaries. As research for one of his *Doctor Who* stories, he studied GCSE astronomy at the Royal Observatory Greenwich - which resulted in an A* and the plot for another *Doctor Who* story. Simon regularly writes for *Horrible Histories Magazine* and medical journal *The Lancet Psychiatry*. With his brother Thomas, Simon also makes films and documentaries - most recently *The Fundamentalist Queen*, about the wife of Oliver Cromwell, broadcast on Radio 3 in December 2014.

Dr Marek Kukula is the Public Astronomer at the Royal Observatory Greenwich, the home of time and space. Originally he wanted to be a Time Lord when he grew up but settled on astronomy as the next most exciting thing, going on to study quasars and distant galaxies with the Hubble Space Telescope. Marek regularly appears on BBC science shows such as *The Sky at Night* and *Bang Goes the Theory* to explain the latest astronomical discoveries and has also turned up in *Doctor Who Confidential*, where he showed Karen Gillan how to view Saturn through a telescope.

*The SCIENTIFIC
SECRETS of*

BBC

DOCTOR WHO

SIMON GUERRIER AND
DR MAREK KUKULA

BBC
BOOKS



'I, too, used to believe in magic, but the Doctor has taught me about science. It is better to believe in science.'

Leela, *Horror of Fang Rock* (1977)

$$\delta^3 \sum x^2$$

INTRODUCTION



‘The TARDIS is outside.’

‘So?’

‘So, all of time and all of space is sitting out there. A big blue box. Please, don’t even argue.’

The Twelfth Doctor and Clara Oswald, *Last Christmas* (2014)

$$\partial^3 \sum x^2$$

How could anyone resist a chance to explore all of time and space? The Doctor offers his companions – and us, watching at home – a chance to venture out into the universe and discover its extraordinary wonders.

On these journeys, we uncover the most astounding secrets. Somewhere out there are creatures made of pure energy and monsters that exist in only two dimensions. There are worlds made of diamond, and stars which are alive. You can rewrite history, regenerate from injuries and, best of all, you can travel to anywhere or when in a blue police box that is bigger on the inside than the outside...

At least, according to *Doctor Who*.

This *isn't* a book about what bits of science *Doctor Who* might have got right or wrong in the more than fifty years that it has been on TV. Getting the science right isn't necessarily the same thing as telling a good story –

although, as we'll see, it's surprising how often bits of real science work their way into the Doctor's adventures. In fact, the series has occasionally been ahead of its time - using the latest scientific theories as the inspiration for stories such as *Earthshock* (1982), or, in stories such as *Planet of the Daleks* (1973), including outlandish-sounding ideas that scientists only later demonstrated to be real phenomena.

This book *won't* detail how you can build your own versions of the technological gadgets that we've seen in the series - robot dogs, sonic screwdrivers or fully working time machines. That said, there is a bit in Chapter 11 about growing your own potatoes.

And this book *isn't* about the intentions of the people who have made *Doctor Who* over the years, and whether or how much they cared about getting the science right. Though that does come up, for example when we discuss the creation of the Cybermen.

Instead, our hope is that the experience of reading this book will be a little like travelling in the TARDIS with the Doctor. Our fifteen thrilling, original *Doctor Who* stories are inspired by the latest and most boggling scientific ideas. Each story is followed by an examination of the real science involved. Using the stories in this book and from the Doctor's TV adventures, we'll explore the strangest, funniest and most astonishing elements of the cosmos.

We hope it's a book to thrill you, make you laugh and think, and ultimately see the world - and the universe - around you differently. *Doctor Who* has been taking us on adventures for more than fifty years, and science is also a great adventure, constantly revealing new things to amaze and astonish us. We hope this book will make you watch *Doctor Who* with new eyes. And we hope it will be just a first step - inspiring you to explore the world of *Doctor Who* and the equally extraordinary world of science still further.

A book, in fact, that's bigger on the inside...

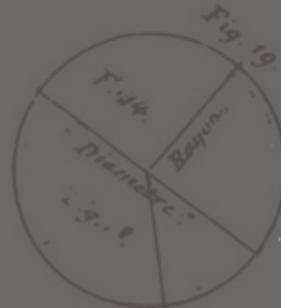
Please note: This book uses examples from all 813 television episodes of *Doctor Who*, from *An Unearthly Child* (1963) to *Last Christmas* (2014). There will be spoilers. Scientific data and *Doctor Who* statistics are correct up to February 2015.

regen = 12



PART 1 SPACE

$$\partial^3 \sum x^2$$



$$XII \geq \textcircled{M} \text{ or } \textcircled{277}$$



SUNSET OVER VENUS

MARK WRIGHT

‘Lovell Platform from *Genetrix*, we have a green board for descent. Await go confirm.’

An alert pinged in Lieutenant Devika Cullen’s earpiece. She glanced across the cockpit to Probe Specialist Rick Attah, who flashed a reassuring grin, then yawned. He reclined in his chair, hands behind his head. They were hanging by a thread 54 kilometres above the surface of Venus, and he looked ready to take a nap. Devika shook her head. Space exploration: a game for the young, as Dad once said.

‘*Genetrix* from Lovell,’ crackled Valeriya Alexandrova over the comms. ‘You have go confirm, cleared for umbilical detach.’

‘Acknowledged, Lovell.’

‘Hey Valeriya,’ Rick broke in. ‘Wanna crack open an alcohol-free tonight?’

The Russian sounded less than keen. ‘You have job to do down there. Fraternising with mission co-ordinator is not part of that job.’

‘See you in the mess at twenty hundred.’

Devika rolled her eyes. ‘You two done?’

Rick grinned and sat up. His body language flowed from bored 24-year-old to alert mission specialist. Rick’s fingers

danced across the instrument panels before and above him. 'Pressure exchange nominal. Good to go.'

'Lovell from *Genetrix*, umbilical detach on my mark.'

'Acknowledged, *Genetrix*.'

Devika sat forward, restraining straps tightening. She glanced at the Heads Up Display, relaying the external camera feed. Below the linked struts and cluster of mission pods that made up International Aeronautical Space Agency Orbital Platform Lovell hung the *Genetrix* manned probe. A long, slender balloon, its surface glistening silver in the sunlight reflected off the thick Venusian cloud. The balloon's material was laced with a discrete dynastream compound, more than enough to deal with the conditions at the edge of the cloud layer. Slung below the balloon was the mission pod, packed with monitoring instruments, systems - and more importantly, herself and Rick.

'Let's ride the Venus Express,' whispered Rick, tensing. This was their third descent from Lovell in as many weeks. Yes, it was becoming routine, something the crew of any long-term space mission had to contend with. What was it Commander Sanford said? *Routine breeds contempt*. It had become a mantra of every member of the Venus mission crew. This might be their third descent but, to both Devika and Rick, it was as dangerous as the first, and they had to be alert.

'Umbilical release in five. Four. Three. Two. One.'

Devika's fingers curled against the release trigger. She took a breath. 'Mark.'

The cockpit lurched. Instead of a sickening drop, the *Genetrix* began a smooth, swooping descent into the carpet of yellow-tinged cloud directly below.

Devika activated controls, her board a line of pleasing green status lights. 'Rick, how's it looking?'

'Check, check, check and check,' he said briskly. 'Systems at nominal.'

‘Check that. Lovell from *Genetrix*, we are descending to cloud layer.’

‘Acknowledged, *Genetrix*. Stay on comms, and happy fishing.’

‘OK, Rick, take us down.’

‘You got it.’ Rick tapped out a sequence.

This was what Devika Cullen loved about her job. Space exploration was exciting, most people agreed, even nearly half a century after the 2049 Moon Crisis. But nothing could describe the feeling of floating down to skim through the upper cloud layer of a planet millions of kilometres from home. Looking out into the stars and taking the human race the next few steps.

But it was dangerous out there. A choking atmosphere, anathema to humans, blistering heat that could scorch flesh from bones. From those twentieth-century pioneers of the old USA and Soviet Union to her hero Adelaide Brooke and beyond, anybody who had ever strapped in and felt the crush of 3 gs as they blasted into orbit knew it was dangerous. But still they came.

Devika felt a flush of heat on her face, droplets of perspiration prickling her brow. She smiled. Environmental systems assured her it was a cool 20 degrees, but it never harmed to remember what was out there, literally inches away.

‘Levelling out at 49 km above the surface of Venus,’ reported Rick.

The HUD relayed an image of thick, sulphurous clouds, tendrils of vapour caressing the screen. They were now inside the cloud layer and perfectly safe at this altitude.

Devika unbuckled and strode to the controls ranged alongside the sealed hatch to the lower level. ‘Atmospheric sifters online,’ she announced. ‘Deploying... now.’

She pulled down on the release triggers. Metallic clangs echoed round the cockpit, one after the other. On the HUD, four lozenge-shaped probes dropped away from the

Genetrix, umbilical hoses snaking back to the mission pod as they vanished into the haze.

Devika toggled her comms. 'Lovell Platform from *Genetrix*, commencing atmospheric skim. Stand by.'

The comms silenced with a beep. Rick blew out a breath. Now, they waited.

Devika perched on the edge of her flight chair. Rick started to sing, tunelessly, under his breath.

'Don't give up the day job, Rick,' said Devika. 'What is that?'

Rick adjusted a control. "'Magic Carpet Ride". Steppenwolf.'

Devika snorted. 'Finger on the pulse, Granddad. Try The Beatles next, they're—'

Devika suddenly pitched forward, head smashing painfully against the metal deck plate. Lights flickered, alarms screamed, status indicators blinked from green to red.

Devika shook her head against the dizziness, vision blurring as she scrabbled onto her chair. 'What the—?' She stopped before completing the sentence, knowing every word they said was heard back on Lovell.

Rick's eyes darted over his control board. 'Pressure mismatch, power drains in all systems.' He turned to face Devika. 'We're dead in the water and dropping further into the cloud layer.'

The HUD screen choked with yellow-stained clouds.

'Lovell Platform from *Genetrix*. We have a problem. Power drain to all systems, pressure mismatch. Descending into cloud layer.' Despite her even, calm tone, Devika's elevated heartbeat would be giving away to her colleagues monitoring up on Lovell that they had a situation. 'Stand by while we investigate.'

Static crackled.

'Lovell Platform, please acknowledge.'

A calm took hold of Devika. Her eyes locked with Rick's. They both knew what this meant.

'Gah!' Rick gasped, the spell broken as something slammed hard against the sealed rear hatch. 'What was that?'

Devika stood. 'Plasma venting?' she offered unconvincingly.

A gentle buzzing penetrated the cockpit.

'Something's out there,' breathed Rick.

The light above the hatch flashed from red to green. Devika gripped the back of her chair so hard her knuckles bleached white.

The hatch slid open, white vapour streaming into the cockpit.

'Hey, how are ya?' barked the tall man who stepped through the venting gas, brandishing a slender probe. Its tip glowed green. He planted booted feet firmly on the deck and pocketed the device. Devika saw a flash of red beneath his long, dark-blue coat. He glared at the astronauts, extending a bony finger to each of them in turn. 'You. You. Blue box out there. In.'

The stunned pair didn't move.

'What the Doctor meant to say,' said a bright voice preceding the young woman peering around the man, 'is that I wanted to watch a Venusian sunset, so we were nearby in our ship when we saw your balloon-thing plunge into the atmosphere. Thought we'd drop in and offer you guys a lift.' She smiled, self-consciously pushing back a strand of dark-brown hair. Then, as an afterthought: 'Hi, I'm Clara.'

The man - the Doctor - cocked his head to one side. 'My version was quicker,' he murmured. 'Come on, shift yourselves!' He clapped his hands, gesturing through the hatch. 'You can say thank you later. If you're lucky, I might even say you're welcome.'

Rick looked at the newcomers, mouth open. Devika found her voice. 'We have valuable equipment and data aboard *Genetrix*. We can't just leave.'

The Doctor's brow furrowed. 'Fair enough,' he shrugged. 'Stay here and die.' With a curt wave, he turned smartly and made to stride through the hatch.

Clara yanked him back. 'Doctor, we have to help.'

'Do we?' asked the Doctor.

'Yes! Unless...' Clara looked up at him, innocent mischief flashing across her eyes. 'Unless you're saying you don't know how you could save the ship?'

The Doctor returned Clara's gaze, then sighed. 'I hate you sometimes.'

Clara grinned. 'No you don't.'

'Right then,' said the Doctor decisively, whipping out the probe-device in one fluid movement. At that second, it felt to Devika like their situation came crashing back in, the alerts shrill and deafening. Her head throbbed, limbs feeling like dead weights, a sickening plunging in her stomach. She ran a hand across her brow; it was slick with sweat and blood. Sweat. The heat, suddenly cloying and oppressive in the cockpit.

The Doctor waved the buzzing probe across a bank of controls, the green glow bright in the flickering half-light.

'What is that thing?' asked Devika, suspicious.

The Doctor gave her a withering look. 'Sonic screwdriver. Obviously.' He returned his attention to the controls. 'I don't know whether to admire the human race, or point and laugh. Bobbing along in your little kiddie's balloon above a meltingly hot world in the name of exploration. Indomitable or stupid, it's a fine line.'

Devika felt a rush of anger. 'Now listen...'

'No!' countered the Doctor, glaring back. 'You listen! Here's what's going to happen. We are plunging at -' he jumped up and down - '3 km per minute into the atmosphere of Venus. Below 30 km, it's going to get messy.'

Fact: the mean temperature on the surface of Venus is 735 degrees Kelvin. The pressure is 92 times that of Earth. Conclusion: the further we fall, we'll either be cooked or crushed. Your choice.'

As if to emphasise his point, a metal panel buckled in on itself.

'Sorry,' said Clara, trying to break the tension. 'He does this. Best to ignore him.'

Devika's gaze had not left the Doctor's watery-blue eyes. 'Instead of lecturing us, help us.'

The Doctor smiled, thinly. 'Better.'

Rick stepped forward. 'What can we do?'

The Doctor raised a finger to the young astronaut. 'Better.'

Clara grinned. 'Come on, Doctor. Let's get these guys home.'

The Doctor was galvanised into action. 'You!' he pointed at Rick, then seemed to look at him properly for the first time. 'How old are you?'

'24.'

'You don't look old enough to shave let alone wear an IASA uniform.' Before Rick could reply, the Doctor waved him away. 'Vent the thermo buffers.'

'Check.' Rick stepped to a rear control bank, his movements sluggish in the increasing pressure.

'Clara, be a pal.' The Doctor threw the probe to her.

'Yes, Doctor?'

'Second level down, control stack to the right of the ladder. Need you to regulate power flow to the pressure exchange. Just point and hope.'

'Gotcha.'

'And don't dilly-dally on the way,' he called after her as she disappeared.

It was now unbearably hot in the cockpit - though the Doctor didn't seem to feel it, even with that coat on. He flicked switches in quick order. 'Need to equalise the

pressure exchange.’ He glanced at Devika. ‘Want to tell me what happened?’

‘Systems went down, no rhyme or reason.’

‘There’s always a rhyme, always a reason.’

‘Thermo buffers vented!’ Rick’s face shone with sweat.

‘Good man.’ The Doctor stepped back, eyes glinting as they darted across every control.

Devika jumped as a bulkhead panel buckled, vapour blasting into the cockpit. The *Genetrix* lurched, forcing her and Rick to steady themselves. The Doctor remained bolt upright, unaffected. ‘Pressure’s building,’ he said, evidently relishing the danger.

Rick pinched the bridge of his nose, Devika feeling the same pain behind her eyes. ‘We’re dead, aren’t we?’

The Doctor nodded. ‘Probably.’ He jabbed at a control. ‘Clara? How’s it coming down there?’

Static crunched. The Doctor frowned, hawkish eyebrows knitting together worriedly. ‘Clara?’

Static hissed, then cleared. ‘Doctor.’ Clara’s tinny voice sounded calm, but there was a wavering note of fear beneath. ‘Get down here. Now.’

The Doctor was already moving, lanky frame vanishing through the hatch. ‘Rick, come on!’ Devika tried to sprint after the Doctor, but only managed a graceless stagger in the ever-increasing pressure.

Devika barely registered the tall blue box standing against a bulkhead before she saw the Doctor launch himself onto the ladder, pivoting round and sliding in one fluid motion to the deck below. ‘Clara,’ he shouted, looking around the stacks of scientific instruments. Devika jumped down next to him, feet slamming heavily to the deck plates. Rick clambered down behind. ‘Clara!’

‘Doctor.’

The Doctor’s head whipped round. Clara stood with her back to an instrument bank, eyes wide. She held the Doctor’s sonic device up, the tip pointing towards...

'Oh man,' whispered Rick. As her eyes followed the probe's direction, Devika could only agree.

Standing - or floating? - a few feet away was a... Devika's mind struggled to put the image into a context she understood. A cloud of dirty yellow vapour floating next to a control stack, constantly shifting tendrils of gas spiralling in a crude approximation of human form. A gaseous life form? Within the miasma, points of light sparkled, the crude humanoid shape completed by two points burning like coals where eyes should have been.

'Oh, look at you,' whispered the Doctor. He grinned, hard lines of his face softening with rapt fascination. 'Look at you.'

'Glad you're so impressed,' said an unmoving Clara.

'What's it doing?' asked Devika. A gaseous arm stretched out, wisps of vapour dissipating as it wafted over a panel. The controls sparked and burned.

'Stop it!' shouted Rick, stepping forward. 'It's screwing with the *Genetrix*.' The movement caused the creature to turn and face them. It hissed angrily, eyes burning brighter.

'Hey, wispy man!' called the Doctor, waving his arms. 'Over here!'

The creature turned with surprising speed. A gaseous arm lashed out, releasing a shower of viscous liquid towards the Doctor.

'Doctor!'

The Doctor whipped about, droplets of liquid spattering across the back of his coat. It began to smoke, the fabric deteriorating as holes formed across its surface.

The Doctor whipped the coat off and hurled it down. Seconds later all that remained were tattered rags of smoking blue and red.

'Oh, Wispy, that was rude,' said the Doctor. The creature turned back to the control stack. The Doctor sniffed at the dirty smoke curling up from the remains of his coat.

'Sulphuric acid. Of course!' He glanced up at his three

companions. 'Fact: sulphuric acid was called "oil of vitriol" by eighth-century alchemists.'

'So?' shouted Rick.

'Man's got a point,' said Clara. 'Stop showing off.' She gestured to the creature. 'What is that?'

'Ladies and gentleman,' announced the Doctor with a theatrical flourish, 'you are looking at the indigenous life form of the planet Venus!'

Devika snorted. 'There can't have been life on Venus for billions of years.'

'You'd think, not since the oceans evaporated,' conceded the Doctor. 'Now, that was a day and a half. But look!' He pointed to the gas creature, the threat of the humans discarded for now. 'Bonded molecules of acidic gas, coalescing, forming and reforming in a pressure cooker of carbon dioxide, nitrogen and sulphuric acid. Life found a way!'

Devika jabbed a finger at the creature. 'And it's tearing my probe apart!'

'Doctor, I can hardly breathe,' said Clara, struggling. Her face flushed red, hair dripping with sweat.

The Doctor didn't seem to hear. He watched the creature spray a fine mist of acid, causing an instrument bank to bubble and melt. Its gaseous head turned to the Doctor. It hissed. Was that desperation?

'Perhaps you deserve it,' the Doctor said, glaring. 'That control bank. What does it do?'

'Regulates the atmospheric sifters,' said Rick.

'Deployment, analysis, everything. The *Genetrix's* prime function is full-spectrum analysis of the Venusian cloud layer, studying the samples to assess terraforming potential.'

'Atmospheric...' mused the Doctor. 'Atmospheric sifters?' His face hardened. 'Tell me you didn't?'

'Are you saying what I think you're saying, Doctor?' asked Clara.

Devika looked from one to the other. 'What? Tell me!'

'You really are as stupid as I thought.' The Doctor's eyes blazed. 'Look at him! Bonded molecules of carbon dioxide, nitrogen and sulphuric acid.'

Realisation dawned on Rick's face. 'Oh, Dev.'

Devika tasted bile as sickening clarity hit her through the noise and chaos. The gas creature - this incredible, impossible life form - stood before them. Outside, the *Genetrix* tumbling towards the surface, atmospheric sifters trailing along with it. Atmospheric sifters sucking in carbon dioxide, nitrogen and sulphuric acid.

'Oh no. Please, no.'

'The penny drops! No wonder Wispy's none too happy. You've been hoovering up his relatives! Purge those sifters, now!'

'On it!' Rick stumbled to the control stack. The creature rounded on him.

'Wispy,' said the Doctor gently. 'May I call you Wispy?' His arms opened wide as he stepped closer. 'I'm not sure if you can understand me, but we need to get to that control bank. Make this right. What do you say? Want to help us out?'

The creature tilted its head in a strangely human pose. With every second that ached by, the temperature rose, breathing now painful, movement sluggish. Wispy began to move. The Doctor let out a relieved breath, face relaxing. He stepped towards the panel, but Wispy lashed out, shrieking in anger. The Doctor dodged back, arms raised protectively.

'Wispy, over here!' Clara staggered towards the creature, now-heavy arms waving as best she could manage. It wailed and moved towards her, away from the controls. Clara backed away. 'Do your work, Doctor!'

'Do it fast!' shouted Rick, jumping in next to Clara.

Wispy stalked after Clara and Rick. Devika was right behind the Doctor as he pounced on the sifter controls,

seemingly unaffected by the pressure bearing down on them. Her vision blurred in the inferno-like heat, confused thoughts bouncing against each other through the stabbing needles of pain in her head. The Doctor snarled, slamming a fist repeatedly against the controls. 'It's fused!'

'We've got to... got to unlock them.'

'Doctor!' It was Clara. Both she and Rick were backed against a bulkhead, the gaseous creature bearing down on them. Above them, a viewport cracked. 'Catch!' She launched the sonic screwdriver across the control room, ducking as the life form sprayed a mist of sulphuric acid that fizzed and burned into the bulkhead above her.

The Doctor caught the device and brought it to bear on the control stack in one motion. 'One chance,' he said, mouth set determinedly. The air filled with an incessant buzzing as the tip glowed green. As her vision darkened, Devika was dimly aware of Wispy turning away from Clara and Rick, eyes incandescent in fury as it bore down on the Doctor.

'Come on, come on!'

The buzzing intensified. Devika slumped to the floor, feeling as if her head were about to explode. The vaporous alien raised both arms towards the Doctor, shrieking in hissing anger, then -

The control stack before the Doctor exploded in a shower of sparks that haloed round him for a split second. 'Got it! Sifter's purging!'

Wispy threw its head back, gaseous tendrils snaking around it, and let out an alien shriek, before its whole form dissipated to nothing. Smoking droplets of acid hissed to the floor, the only evidence it had ever been there.

The Doctor pulled Devika to her feet. Clara stumbled forwards, supporting Rick. The *Genetrix* shuddered.

'Still falling,' Devika wheezed. She slumped to the floor, pressure forcing her down, lungs burning as she tried to suck in air. The four huddled together beneath the ladder.

‘Nothing I can do,’ said the Doctor. A control panel buckled as if punched, sparks billowing and fizzing onto the deck plates ‘Up the ladder, into the TARDIS.’

‘The what?’ asked Rick.

Clara heaved him forward. ‘The big blue box! Move!’

‘Quickly!’ urged the Doctor. The whole craft shook, dirty yellow Venusian clouds billowing past the viewport, the heat now an unbearable, cloying haze. ‘We’ve got seconds before—’

The shaking ceased. The Doctor stopped mid-sentence, one foot on the bottom rung. A serene calm took over, alarms silenced, warning lights blinked off one by one. Almost immediately it felt easier to breath, Devika sucking in a lungful of cooler air.

Rick tapped at a readout screen. ‘We’re rising,’ he said, that grin spreading across his youthful features.

The Doctor looked dubious. ‘Can’t be. I haven’t done anything.’

Devika let out a heavy breath. The temperature was cooling all the time.

Clara stood on tiptoe, peering out through the cracked viewport. ‘Guys. You really need to see this.’

Devika crowded in behind Clara. She suddenly felt as light as air. The Venusian clouds still rolled and boiled in the void, but there was something else. Gas creatures, gliding and swooping around the *Genetrix*, their glowing eyes shining like fireflies. There must have been fifty or more, whirling in a circle beneath them, a vortex of these amazing life forms.

‘They’re taking us up,’ breathed Devika.

The Doctor stood behind them, arms folded, face implacable. ‘Good old Wispy.’

‘... *trix*, please respond. *Genetrix* from Lovell Platform, please advise status.’

Devika and Clara continued to watch. Rick toggled the comms. ‘Lovell Platform from *Genetrix*. We’re fine, status...

erm...? What do I say?’

Devika smiled, glancing at the Doctor. ‘Tell them they’d never believe us.’



Two hours later, Devika Cullen, Rick Attah, Clara and the Doctor looked out from Lovell’s observation deck. A thick carpet of yellow cloud stretched away in all directions. On the far horizon, a fuzzy yellow-orange orb was half submerged in the clouds, light stretching out to highlight the atmosphere in brilliant colour.

Clara sighed happily. ‘I thought I was going to miss my sunset.’

‘A day on Venus lasts 116.75 Earth days,’ said the Doctor. ‘The sunsets here are a sublimely leisurely experience. Plenty of time.’

‘It looks like a melting ice cream.’

The Doctor rolled his eyes.

They continued to watch in silence. Below the platform hung the *Genetrix*, the silver balloon secure in its umbilical. Devika tried to retain the memory of their flight back to Lovell. The Wispies - as Clara now called them - pushing them up through the clouds, temperature and pressure receding by the second. Up and up, until Lovell came into sight and they were able to reattach to the umbilical. Seconds later, the Wispies plunged back towards Venus, diving through the cloud layer as if it were an ocean.

Devika turned to the Doctor. His face reflected the light from below. ‘Commander Sanford is speaking to IASA Command on Earth about how we best protect this life form. We’ll do better, I promise.’

The Doctor’s expression didn’t change. ‘I’ll be watching, so make sure you do. You got lucky today. Very lucky.’

‘It was OK in the end, right?’ said Clara.

'Just. But here's the thing.' The Doctor turned to face them, tall frame highlighted against yellow Venusian cloud and the inky black carapace of space above. 'Humanity needs to buckle up. You're expanding, setting off through the stars. I envy you the discovery, but out there...' He opened his arms wide, gesturing into space. 'Out there, beyond the Solar System, there are even more strange, fantastical, dangerous things to discover.'

The Doctor looked at each of them in turn, Devika and Rick hanging on his every word. Clara smiled as he continued.

'You thought today was scary - you just see what's waiting out there.' And he grinned.



ALIEN LIFE AND OTHER WORLDS



'I've had a life with you for 19 years, but then I met the Doctor, and all the things I've seen him do for me, for you, for all of us. For the whole stupid planet and every planet out there.'

Rose Tyler, *Doomsday* (2006)

$$\partial^3 \sum x^2$$

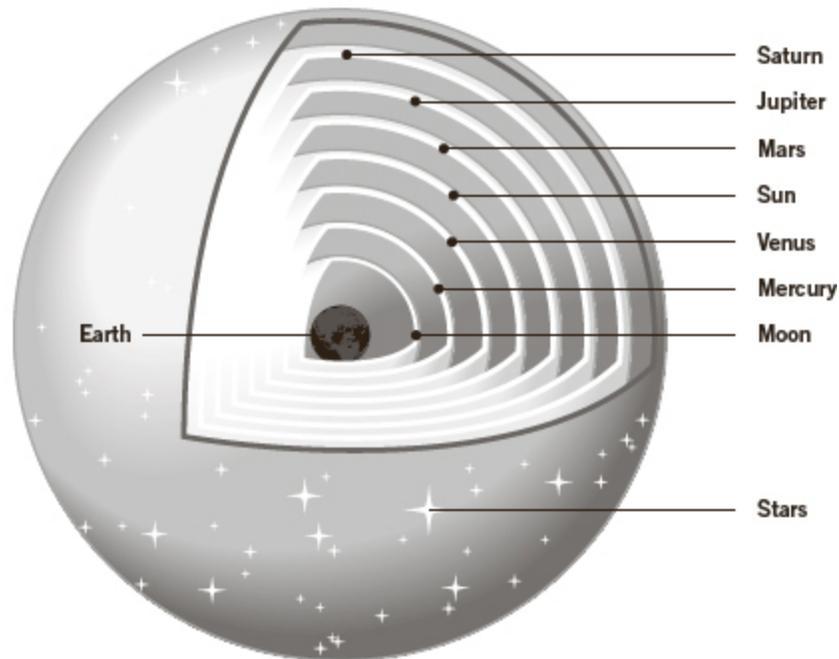
Until 24 August 2006 – a month after the first broadcast of the Tenth Doctor episode, *Doomsday* – we didn't know what a planet was.

The word 'planet' means 'wanderer' and dates back thousands of years to the ancient Greeks. But their ideas about what they saw when they looked up in the sky were very different from what we understand now. They thought the Earth was at the centre of the cosmos, surrounded by a series of huge, revolving, crystal spheres. Each of the first seven spheres had a planet fixed to it – and these seven 'planets' included the Sun and Moon. On the eighth and outermost sphere were fixed all the stars.

OK, the ancient Greeks got it wrong, but – as *Doctor Who* shows us when the TARDIS lands in the past – people in history weren't stupid. They were just as clever and

inventive as we are. Today, we have ever more powerful telescopes to look deep into space. We send spacecraft and robots to explore the planets near us - such as Venus - and gaze further out into the universe. But for a long time, all people could use to explore the heavens was the naked eye and some clever thinking.

The ancient Greek model of the planets



Imagine a room with a wheel fixed on the wall. The wheel is side-on, so it looks like a disc - a circle. The circle is spattered with blobs of white paint. Turn off the lights and you can't see the circle but the paint blobs glow in the dark. They look like a pattern of stars. Then the pattern of blobs starts to move, all together, spinning round and round.

What must be happening? The obvious answer is that the wheel is turning. It doesn't matter that you can't see the wheel in the darkness; you can work it out easily from the way the blobs move. If you'd never seen the wheel - if you'd only entered the room when the lights were already

off - you'd still quickly work out that the glowing blobs were fixed to something that was spinning round.

What you probably *wouldn't* think is that the blobs were keeping still and *you* were the one who was spinning. That would be ridiculous! How could you be turning upside down but not feel you were moving at all?

Except, of course, that that is exactly what's happening when we look up at the stars. They slowly turn through the night sky, as if they're fixed on something like a wheel. But they look like that because our planet - Earth - is turning on its axis. We're the ones going round.



'It's like when you're a kid. The first time they tell you the world's turning and you just can't quite believe it because everything looks like it's standing still. I can feel it. The turn of the Earth. The ground beneath our feet is spinning at a thousand miles an hour, and the entire planet is hurtling round the Sun at 67,000 miles an hour, and I can feel it. We're falling through space, you and me, clinging to the skin of this tiny little world, and if we let go...'

The Ninth Doctor, *Rose* (2005)

$$\partial^3 \sum x^2$$

Frankly, a lot of what we now know about other planets - and our own - is a bit weird and unsettling. It's certainly not obvious. So how did we puzzle it out? Unlike the Doctor, we can't feel the turn of the Earth beneath us. We don't have a TARDIS to take us to other planets for a quick look round.

But what does the Doctor do when he lands on an alien world where something strange is happening? He explores, looks for clues and asks awkward questions (sometimes getting himself in trouble with whoever's in charge). That's also how, over thousands of years, we puzzled out what planets really are.

Let's go back to the beginning. Why did the ancient Greeks think the planets were fixed to glass spheres?

As we saw, it looks as if the pattern of stars is slowly turning round and round, fixed to something like a wheel that we can't see. But the stars aren't the only lights in the sky. There are the Sun and the Moon. Then there are a whole lot of things that, with the naked eye, look like the other stars but don't behave in the same way. Instead of turning round and round as part of one fixed pattern, these stars seem to 'wander' about from night to night. The ancient Greek word for wanderers was πλανῆται - 'planetai'.

The Sun was the easiest to see of these planetai, and its movements were the easiest to understand - or that was how it seemed. Every morning, the Sun rises in the east. It then gets slowly higher in the sky until midday, starts to sink again in the afternoon and finally sets in the west. We don't see it at night but it's back in the east by next morning. It seemed obvious that the Sun circled round us.

Less obvious was explaining why the Sun's position in the sky at midday was much higher in the summer than it is in winter. We now know that the Earth is slightly tilted as it spins round the Sun. When the tilt means we point towards the Sun, we get more hours and a greater density of sunlight - our summer. At the same time we have our summer, the other side of the Earth tilts away from the Sun so is in winter. But ancient civilisations thought the Sun went round the Earth, so they came up with different explanations.