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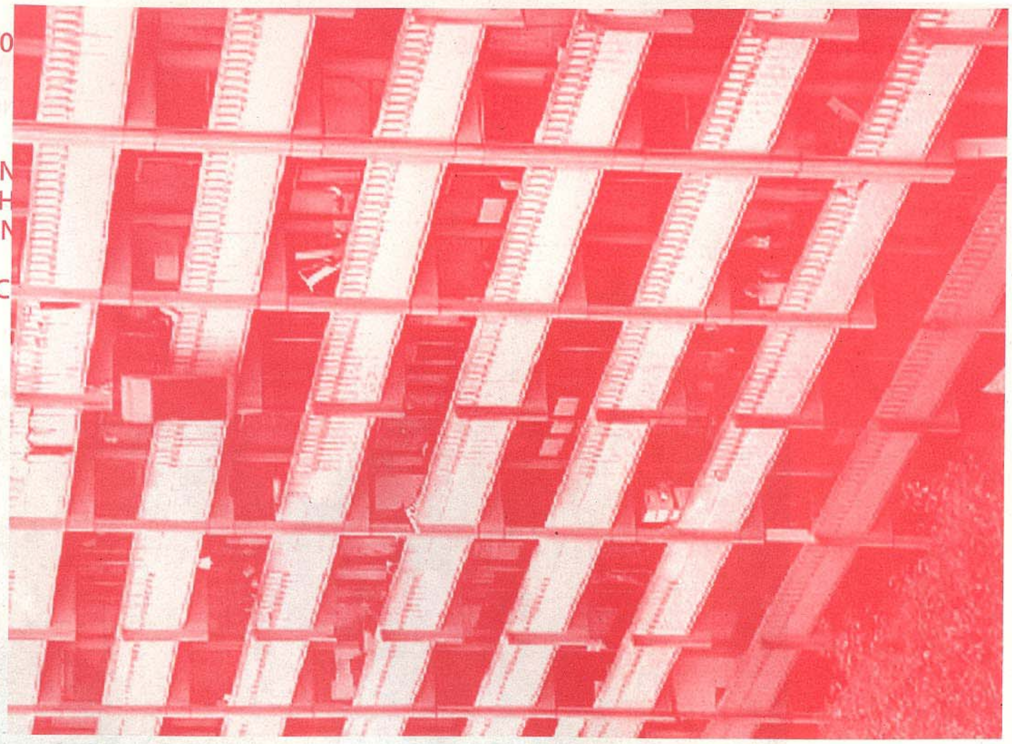

Sofa stills, Amsterdam, 2004

To fall is to understand the universe

By Martijn van Calmthout

Isaac Newton didn't know what exactly what gravity is either. He could precisely calculate how masses attracted each other: more forcefully the heavier they are and more weakly the further apart they are. The mathematical formula in which he expressed it about three hundred years ago made him one of the first real physicists. Many would say the greatest.

But he had little to say about what gravity actually is. I've no idea, I presume nothing. Hypotheses non fingur. It was enough for him that gravity could be expressed in a formula.

All the same, it remains an obvious question: what is gravity? If only because gravity is in fact the only force we are continuously aware of. Modern physics tells us that there are four forces in the universe. One force that has to do with electricity and magnetism. Two forces that control atoms. And gravity, which had entire planets in its grasp.

That may sound impressive, but gravity is the weakest force we know. If a stone is dropped it falls faster and faster. But when it hits the ground that force is immediately spent. The electromagnetic forces of the ground stop it abruptly, easily compensating for the weight pressing the stone onto the ground. The stone is at a standstill.

The interplay of forces of the motionless stone is what we ordinarily associate the most with gravity. We feel how we are pressed into the chair we are sitting on. We feel the shopping bags pulling on our arms. And we know that what is doing the pulling is the earth. The whole earth. When we jump it pulls us back immediately.

How hard the earth pulls depends on just one thing: mass, measured in kilograms. Kilograms of what, doesn't matter. A kilo of feathers is pulled as hard as a kilo of lead. They weigh the same, one kilo. They exert the same pressure on the scales. One Newton of pressure, say the physicists.

So there is a pull. But how does it actually work? There's no rope stretched between the moon and the earth. And yet the earth pulls its satellite in such a way that it remains in its orbit. There are no hefty rubber bands confining us to our chair, no sturdy ropes holding back the jumper. And yet that's how it feels. So what is exerting the pull?

It was not until the beginning of the twentieth century that science found an answer to this. The answer came from a 28 year old office clerk working in the Swiss Patents Office in Bern. His name was Albert Einstein. He worked out, just by thinking about it, what gravity actually is. His answer, however, is difficult to really comprehend. Gravity, said Einstein after an exhaustive mathematical quest between 1907 and 1915, is what we feel of the curving of the space and time that constitutes the universe.

It began with a fall. Einstein had thought up the theory of relativity on his own in 1905. This theory describes how space and time conspire with just one aim: that the speed of light is the same for all observers, whether they race along with it as fast as they can or remain immobile. Einstein calculated that in that case moving measuring rods are shorter than motionless ones. And that moving clocks run slower than immobile ones.

In 1907 the theory of relativity began to make a bit of a name for itself and Einstein was allowed to write a paper about it for the German physicists association annual. But he was dissatisfied. His theory actually applied only to observers whose velocity is constant and each of whom could maintain that they were motionless and that the rest were moving around them. Whereas in real physics the main thing is acceleration. Forces accelerate objects. When we accelerate in the car, our back is pressed against the seat.

Sunk in thought, Einstein went to his job at the Patent Office and sat at his desk pondering, dealing mechanically with his work. Could his relativity theory also apply to acceleration?

One morning in November 1907 he realised something simple: someone falling experiences zero gravity. Such an observer can therefore maintain that he is inertial, floating, just like the observers in the 1905 theory. In principle, therefore, the same had to apply to accelerated observers. On the condition that the extended theory also has something to say about gravity. Einstein later called this intuition the most fortunate thought of his life.

Einstein thought further. If a falling man experiences no gravity, can acceleration then be experienced as gravity? He imagined a box. A box standing on earth. In the box is a man. He experiences gravity. If he drops his keys they fall down. Because of gravity.

Second thought experiment. Now the box is floating in empty space, far away from all the planets. At the top there's a rope. The rope is pulled, causing the box to rise quickly. The man in the box feels a downward force, a force that feels no different from gravity. If he drops his keys again they fall to the ground in completely the same way. With an accelerated movement.

According to Einstein, the two situations are indistinguishable. Gravity and acceleration lead to the same observations and sensations. The mass pulled at by gravity is by definition the mass that resists acceleration. For centuries physicists had wondered why the two could be so identical. Einstein finally realised why: it was because it is a matter of the same situation, just differently described.

But what is this gravity, then? Imagine that there is light coming into the box through a hole in its wall and that the box is pulled upwards through empty space. While the light shines onto the opposite wall, the box rises a little. The spot of light on the wall thus appears a bit lower than where the hole is. The man in the box sees the light pulled slightly downwards.

But the man does not know what is happening with the box. Perhaps he is being pulled up faster. Perhaps he is subject to the earth's gravity, motionless. Therefore only one conclusion is possible: gravity also causes the beam of light to curve And since paths of light form as it were the squared paper onto which the reality of the universe is projected, gravity therefore warps the universe itself.

In 1915, after years of calculating and endless trials, Einstein found a way of expressing this in a formula. It was wartime. Nobody outside Germany was listening. But what it came down to in words is at once simple and unimaginable. "Mass, said Einstein, exerts a pressure on its surroundings because it warps the space-time continuum around it."

It's a bit like a bowling ball laid upon a mattress. The ball pushes into the mattress, creating a dent. If you try to roll a marble just past the bowling ball you'll find that because of the curve of the mattress the marble does not go in a straight line, but deviates in the direction of the ball. It is pulled away from its straight path.

Gravity is a deformation of the matter that constitutes the universe as a whole, a deformation of space and time. In itself this deformation is too subtle to be perceived directly. But it is clearly present in the natural tendency of everything around us to fall and to be weighable.

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