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WEEKLY 2 September 2023

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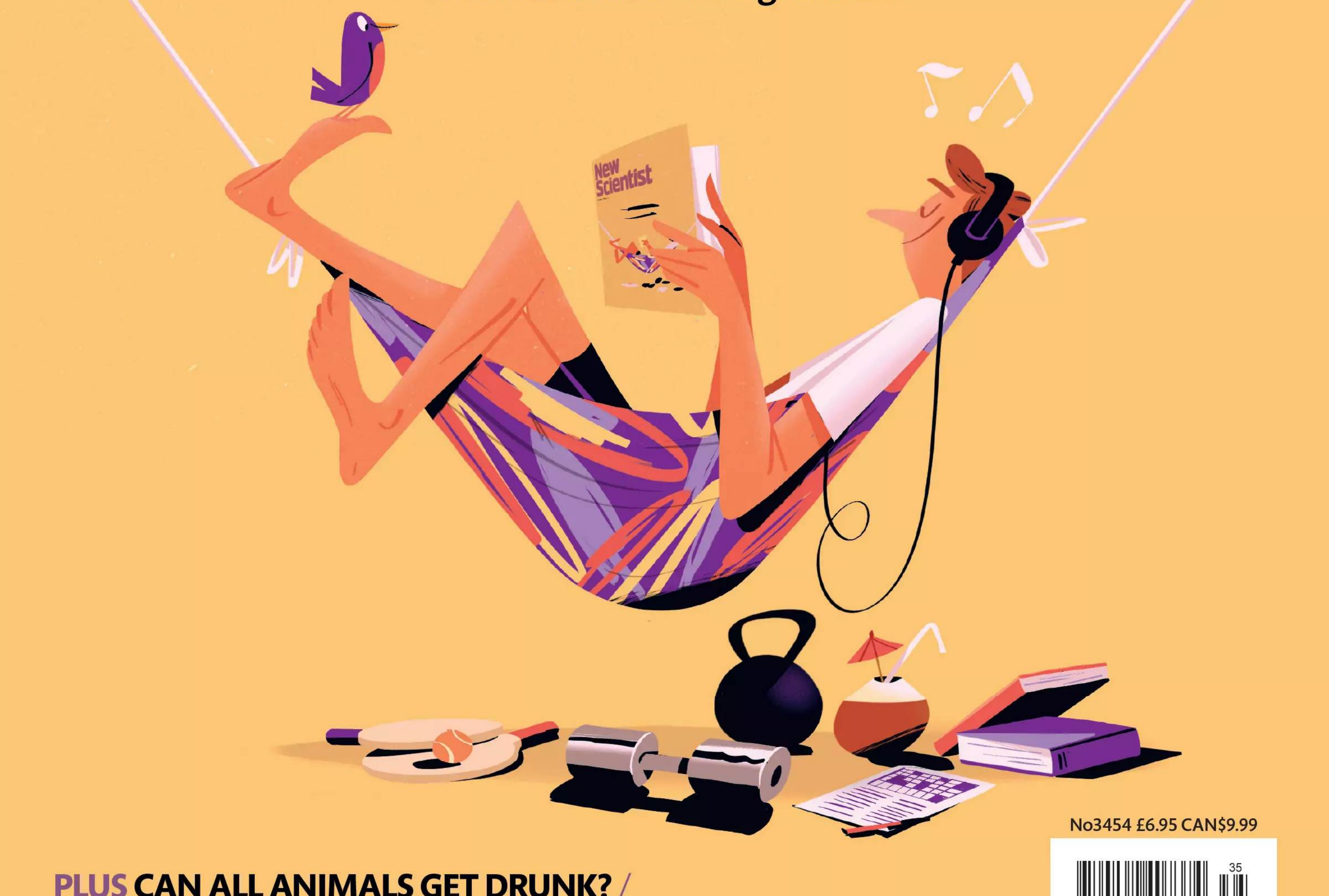

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"We're exploring the habitability of the moons of Jupiter"

The JUICE mission can finally tell us whether conditions on Jupiter's icy satellite worlds are conducive to life, physicist **Michele Dougherty** tells Becca Caddy

DECADES-LONG space missions are planned down to the second. The exact routes the craft travel through the solar system are meticulously mapped out, based on years of design and testing. If you want to deviate from these, you had better have a compelling reason.

But that is precisely what happened in 2005, during NASA's Cassini mission to Saturn. Upon seeing something unusual, Michele Dougherty, a physicist at Imperial College London, asked for a closer look at one of Saturn's moons, Enceladus. What the probe saw was incredible: massive plumes of water vapour erupting from cracks at the moon's south pole.

Today, with Cassini long gone, Dougherty is looking forward to making further unusual discoveries, as the principal investigator on the Jupiter Icy Moons Explorer (JUICE) mission operated by the European Space Agency (ESA). This project, which launched in April, has a clear goal: to better understand whether Jupiter's moons have the right ingredients to harbour life.

Jupiter has between 80 and 95 moons, but JUICE will focus on three of its four biggest. It will fly by Europa, Ganymede – the largest moon in the solar system – and Callisto, before going into orbit around Ganymede.

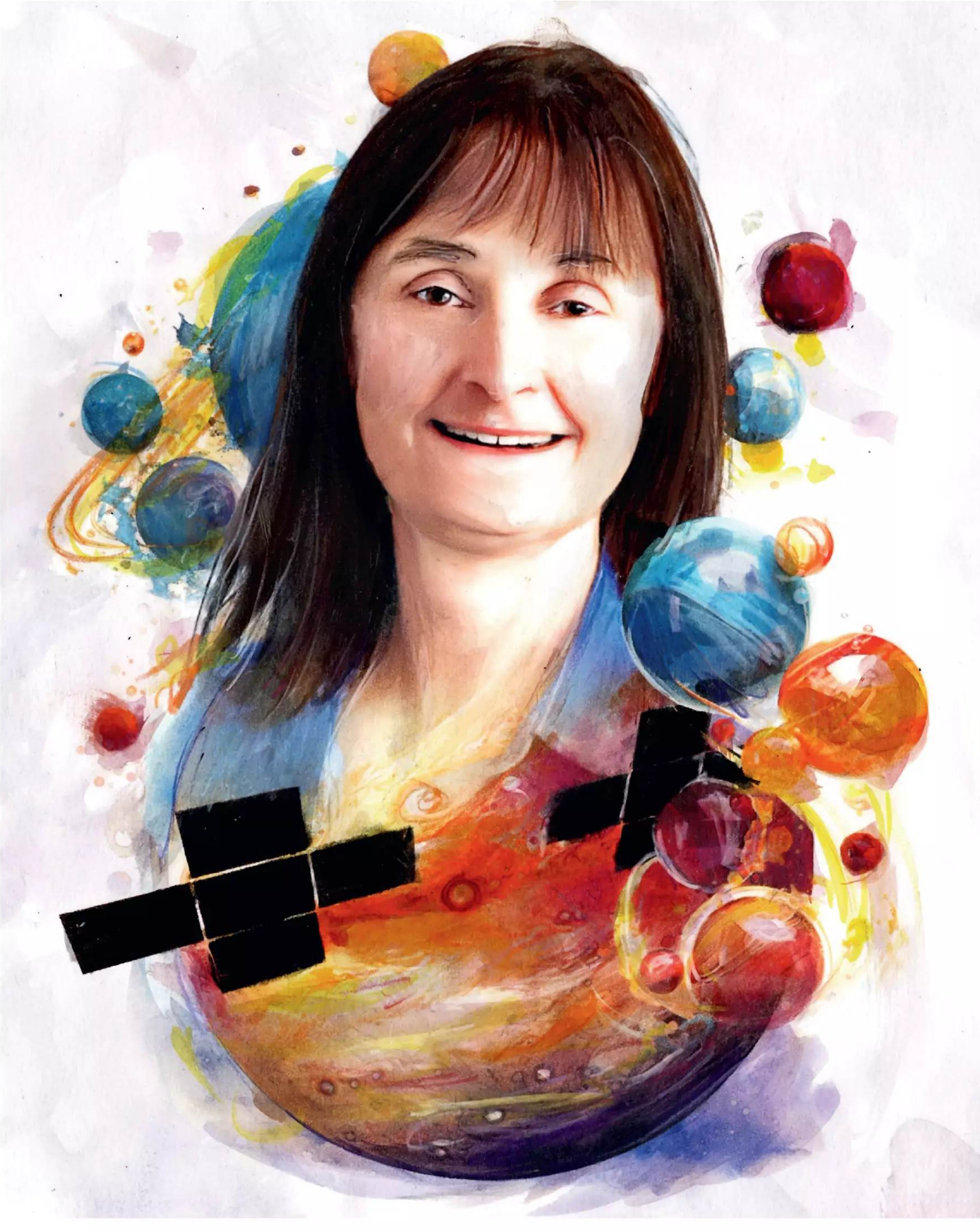
Dougherty tells *New Scientist* why we need to be open to the unexpected secrets that could lurk beneath the icy exteriors of these worlds and how she plans to reveal them.

Becca Caddy: How did it feel to change the course of the Cassini mission?

Michele Dougherty: That was quite scary. My team and I saw something in our data that didn't make sense. One way we could describe it was if there was an atmosphere on Enceladus, but at first I was concerned we hadn't calibrated our data properly. The spacecraft was moving very quickly, so it took a while for us to get the high-resolution spacecraft trajectory data.

Then we saw the same signature on a second flyby, so I took a chance and said: "We're seeing an atmosphere, can we go close?" It took a bit of persuasion, but the majority of the team said yes. It was a very nervous time for me. If we had changed the spacecraft's planned route and hadn't seen anything, I wouldn't have been held in the regard that I am now held.

Luckily, what we found was spectacular. It turns out it wasn't an atmosphere, but an outgassing of water vapour at the south pole. Now, thanks to this discovery, there's a focus on Enceladus as a place where life might form, so it was a really positive outcome. But it was a bit chancy.



NABIL NEZZAR

Was it tough when the Cassini mission finished?
By the end, we were all exhausted. We simply couldn't keep it up anymore. Part of me was almost relieved. I was watching it end at NASA's Jet Propulsion Laboratory. A graph shows a signal from the spacecraft as a spike in the data. As long as you see the spike, the spacecraft is talking to Earth.

The spike disappeared, and then it came back again. No one had told the spacecraft that the mission was ending. It had been trained to keep talking to Earth and moved so it could continue. The spike came back, very briefly. Then the spacecraft began to tumble towards Saturn, where it would burn up. And, as relieved as we were, that's also 25 years of your life done. For me, that was the most emotional part of the mission.

How does your experience of JUICE compare with Cassini so far?
I was fortunate to get involved in Cassini around the time of its launch. For JUICE, I led the science definition team, where we came up with the idea, so it's been my baby for 15 years. I've been involved in designing and building it, and persuading ESA to fly it. So, the launch was worse for JUICE. It was nerve-wracking. I couldn't wait for it to be over.

Has that worry alleviated now it is in orbit?
Once JUICE was up there, I suddenly remembered what it felt like to have an instrument in space. You wake up every morning and check your email to make sure everything's OK. There's always a slight frisson of fear. But I know there will be problems with the instruments, there always are. Something won't work and we'll have to check something out. It happens with space instruments.

But you calm down after the first month. You can't live like that forever. And if something goes wrong, you deal with it. That's what you must do if you have an instrument in space.

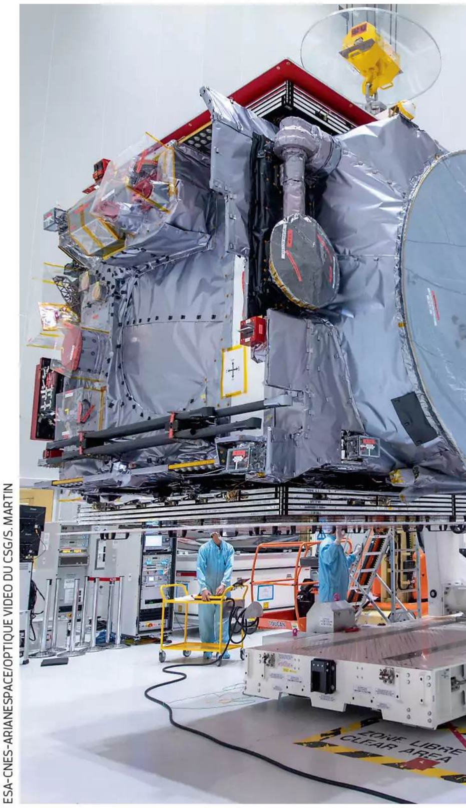
What are you hoping to find with the JUICE mission?
The main driver is to explore the potential habitability of the moons of Jupiter. That's the case that we made to ESA when they selected us 15 years ago. In some ways, we're halfway through the mission. In 15 years, we'll be getting our last bits of data.

Which moons will you be looking at specifically, and what will you be looking for?
We aim to better understand the ocean on Europa. We also want to understand the surface of Callisto, which is extremely odd, and its internal structure. We don't think it's differentiated, meaning there's no solid core with different layers above it like at Europa and Ganymede. And although we don't quite understand why, we're almost certain there's a liquid water ocean under the surface, and we want to characterise that.

For me, though, the real focus is Ganymede. We want to understand if its ocean is global. How deep is it? What's the salt content? The other exciting thing about Ganymede is that it will allow us to understand a whole new class of planetary bodies called water worlds. We think that some exoplanets have numerous water worlds in orbit around them.

Your team is responsible for JUICE's J-MAG, which is a magnetometer. Why is it important to have this instrument on this kind of mission?
One of the most important things we've managed to discover in the past 20-odd years, and I think Cassini really helped consolidate this, is that the instruments my team and I build are useful for not only understanding

"It's what we don't know we're going to find that I'm most interested in"



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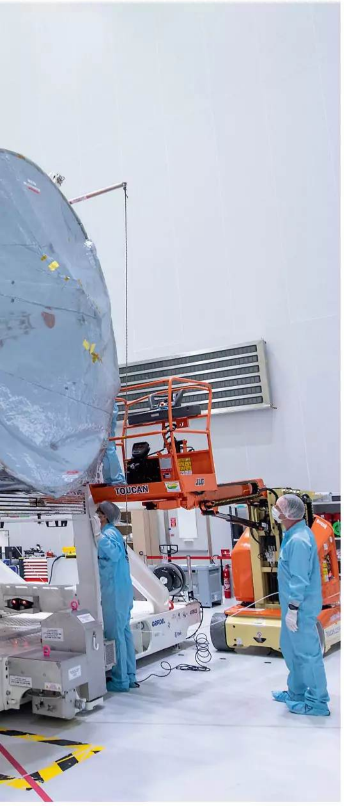
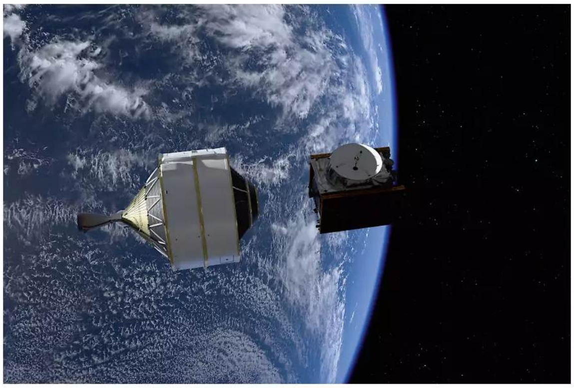
NASA/JPL-CALTECH/SWRI/MSSS

The JUICE mission will study three moons of Jupiter, including Europa





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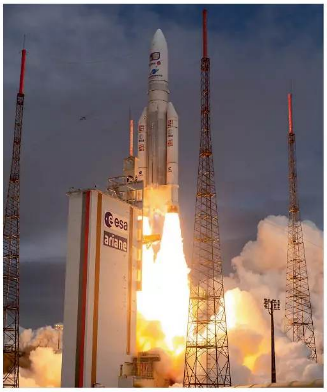

ESA/STEPHANE CORVAJA

The European Space Agency's JUICE probe (left) launched in April this year (right). It is now on its way to study three of Jupiter's moons (artist's impression above)

the environments on planets or moons. They allow us to see inside those planetary bodies.

Take Ganymede, for example. It is the only moon in the solar system with its own internal dynamo field, a magnetic field caused by liquid metals moving around, like we have on Earth. So, we can study that with our instrument, but we need to separate all sorts of different magnetic fields, from Ganymede and Jupiter.

We like to describe it as trying to find needles in a haystack, but they're changing shape and colour all the time. That's why we need to go into orbit to see.

How close will JUICE get to Ganymede?

That's one of the great things about the JUICE launch: the Ariane 5 rocket launch was so precise that we didn't need to use any extra fuel to get us on the right trajectory, so we saved a lot of fuel. That means we can get closer to Ganymede than we planned. We'll start off orbiting at 500 kilometres, and we will reinstate the 200-kilometre phase, which we had taken out because we were concerned we weren't going to have enough fuel to do it.

Are you expecting to find life on these moons?

When we made the case to ESA to choose JUICE, I told the team they weren't allowed to mention the word "life". We are talking about potential habitability, yes. But the most important realisation we've made is that the icy moons in our solar system potentially have the ingredients to harbour life.

Our understanding of how life forms and evolves is that you need these different ingredients. You need liquid water – that's the first thing we look for. You need a heat source. You need organic material. And then you need those three ingredients to be stable enough over a long enough period of time that something can happen. Those are the ingredients we're searching for.

And that's why we get so excited when we realise there's liquid water under the surface of some of the moons. Experiments were carried out in the deep oceans on Earth, where the temperatures are really low and the pressures are very high. Where there are thermal vents down in these deep oceans, bacteria have been found. So that's what you need: heat, water and organic material.

Which places in the solar system are likely to have these ingredients?

In the past, the focus has always been on finding liquid water and looking at Mars because it's close to the sun. But following the Galileo [an earlier mission to Jupiter and its moons] and Cassini missions, we now realise there's liquid water elsewhere in our solar system, beyond the snow line – where if there was water on the surface, it would be ice. From my perspective, at Saturn, we've got Enceladus and Titan. At Jupiter, we've got Europa, Ganymede and Callisto. Those five potentially have the ingredients – Uranus and Neptune's moons might do as well.

Do you have your sights on those last two?

I see us as explorers. I don't mind where we go next. I will be very old before we get something to Uranus. But that's OK. We're on the path to exploring our solar system.

What are you most excited to find with JUICE?

I want to find out more about the ocean on Ganymede. Assuming all goes well, we'll do that. That's going to be our focus.

But it is what we don't know we're going to find that I'm most interested in. Just as we had something unexpected crop up during the Cassini mission, that's what I hope is going to happen on JUICE. I can't predict what that will be. I'm just looking forward to something I'm not expecting. ■

Becca Caddy is a freelance writer based in Yorkshire, UK