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978-0-521-81207-8 - New Worlds in the Cosmos: The Discovery of Exoplanets

Michel Mayor and Pierre-Yves Frei

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New Worlds in the Cosmos

The Discovery of Exoplanets

With the discovery in 1995 of the first planet orbiting another ordinary star, we know that planets are not unique to our own Solar System. For centuries, humanity has wondered whether we are alone in the Universe. We are now finally one step closer to knowing the answer. The quest for exoplanets is an exciting one, because it holds the possibility that one day we might find life elsewhere in the Universe, born in the light of another sun. Written from the perspective of a key player in the scientific adventure, this exciting account describes the development of the modern observing technique that has enabled astronomers to find so many planets orbiting around other stars. It reveals the wealth of new planets that have now been discovered outside our Solar System, and what this means in terms of finding other life in the Universe.

MICHEL MAYOR is Director of the Observatory of Geneva, Switzerland. In 1995, together with Didier Queloz, he discovered the first extrasolar planet (51 Peg b) around a main sequence star, and has discovered many more since. His work earned him the prestigious Balzan Prize 2000.

PIERRE-YVES FREI is a science journalist with the Swiss newspaper, Lausanne Hebdo. In 1998 he was awarded the Media Prize for science popularisation.

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MICHEL MAYOR

AND

PIERRE-YVES FREI

Translated by Boud Roukema



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Preface

Do there exist many worlds, or is there only one?
That is one of the noblest and most exhilarating questions
in the study of nature.

Albert the Great (13th century AD)

It had to happen at some time or another that someone would look up at the sky and wonder about the nature of the stars. When did this first happen? Undoubtedly, long ago. The first explicit clues linked with astronomical activities date to several millenia before Christ. Just think of Stonehenge, the famous site in England, or of some of the ancient ruins inherited from the Sumerian and Babylonian civilisations.

It was with Greeks that astronomy started to distance itself from the influence of myth and religion. The sky, as well as the Earth, became an object of study, an object of observation, an object of science. Nature became less and less spiritual, and more and more material. However, the arrival of Greek thought did not stop speculation.

In the fourth century BC, the Greek philosopher Epicurus (341–270 BC) asked the fundamental and dizzying question: are we alone in the Universe? Nowadays we know that this question has a real scientific relevance. At the time, it was much less obvious. For the immense majority of Epicurus' contemporaries, at least for those interested in the question, the Universe was closed, bounded by a sphere on which the stars were fixed. But Epicurus did not see things this way at all. For him, the Universe was huge, so deep that it was impossible to determine its size. And in such vastness, he concluded that there had to exist infinitely many worlds, of which some certainly had to support life.

A lot of the history of astronomy tells the story of this quest for other worlds in some way or another. Over the centuries, from

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discovery to discovery, the cosmos has continued to swell and to be populated. Thanks to Copernicus, the Sun has taken the place it deserves, at the centre of the Solar System. With the arrival of the refracting telescope, Galileo and his successors discovered new planets. Saturn lost its claim to be the furthest planet from the Sun in the Solar System, handing the title over first to Uranus, then to Neptune and finally to Pluto. Uranus revealed itself first, then Neptune, then Pluto. It was also realised that the stars lie at incredibly great distances and that they are like other suns. There was no reason to believe that they had no planets. All that was needed was to prove that they did.

Today we have that proof. With the discovery in 1995 of the first exoplanet¹ around an ordinary star, 51 Pegasus, we know that the planetary phenomenon is not a privilege unique to the Solar System. So, Epicurus was right. In just seven years, over a hundred exoplanets have been discovered. Nearly all of them were detected indirectly, using the gravitational influence they exert on their associated central stars. This was the only way to be sure of their existence. And if the discoverers of the exoplanets are to claim any merit, then it could be that of having arrived at the time, at the turn of the twentieth century, when progress has provided a detection technique, that of the spectrography of radial velocities, which succeeded where others had previously failed, at times by a hair's breadth.

Already more than a hundred exoplanets have been discovered, and the astronomers' basket is still far from being filled. Massive resources have now been committed in order to push this number to several hundred, and undoubtedly in the near future to several thousand. This is because we need to have a large number of these exoplanets in order to better understand the conditions that led to their formation. True, a beautiful theory of planetary formation had already been constructed, based on the study of all sorts of properties

¹ We have got used to calling planets outside of the Solar System 'exoplanets'.

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of the Solar System. But unfortunately or fortunately, according to one's view, the exoplanets discovered up to now aren't at all like those of our solar system. When they're not virtually stuck to their central star, they have particularly eccentric orbits. All the data point to a need to reformulate most of the theory of planet formation. A challenging perspective.

But what is even more exciting is the very realistic prospect of discovering life elsewhere than on Earth. Science fiction has already given us a tempting foretaste of this. It underlines our overwhelming desire to know if we are alone in the Universe. At the moment, we can't say anything definitive. But it is hard to believe that among the billions and billions of stars in our Galaxy, the Milky Way, and the billions of galaxies that inhabit the Universe, the Sun is the only one accompanied by a living planet. It's likely that life has conquered other planets, even if only in a primitive, unicellular form. In the Solar System, life could have chosen other playgrounds: there's Mars, a quasi-twin sister of the Earth, but also Europa, one of the four big moons of Jupiter, which could hide marvels beneath its frozen surface. Several space missions are planned that will look for signs of past or present extraterrestrial life.

Nevertheless, one thing is sure: the Solar System does not harbour another blue planet. To find a cousin of the Earth, it will be necessary to go further, maybe even much further. The closest star to the Sun is 4.2 light-years away, a considerable distance, especially when you are trying to observe a planet which produces no light of its own. So, is it mission impossible? Not if one believes the astronomers, who have already thought of techniques that will make it possible to 'see' these extrasolar earths. Some projects, more ambitious yet, but still scientifically sound, plan to photograph those same earths, at least if they're not too far away. In which case, we will see them in their true colours, in blue, white and brown. Will we see the first extrasolar portrait before 2050?

If, by good fortune, such a pearl of life is found, it is certain that radio astronomers, some of whom have been scrutinising the sky

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since the 1950s in search of an extraterrestrial signal, will direct their antennae towards this new world. Maybe, humanity will then finally learn that we are not alone in the Universe.

The aim of this book is to provide its readers with a glimpse of the quest for exoplanets, to show them that even though this discovery constitutes an important event, it's only a link in the tremendous chain of knowledge and questions which leads to what will possibly be one of the greatest moments in the history of Mankind.

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I should emphasise here that the discovery of the companion of 51 Pegasus was not the work of just one or even of just two researchers. Astronomy today requires ever more powerful and sophisticated instruments, the development of which cannot occur other than as the result of close teamwork.

The spectrographs that we used in order to obtain our harvest of planets would not have seen the light of day had it not been for the invaluable help of numerous specialists from the Observatories of Geneva and Haute-Provence, in domains as diverse as optics, mechanics, electronics and, of course, computer hardware and software. I'm particularly grateful to my friend André Baranne, the 'magician' to whom we owe the extraordinary quality of the optics of the Élodie spectrograph, the true cornerstone of the experiment. A very big thank you also goes to Didier Queloz not only for his very pleasant company during our numerous – and in certain cases historic – observing campaigns, but also for his skills in perfecting the software that presently runs Élodie and without which our instrument would never have reached its full potential.

To go from a simple idea to the completion of such complex and precise machines took many years of effort, years during which at times there were moments of doubt. Luckily, we have been able to count on the support, the help, the faith and the enthusiasm of many people. They should all be thanked for having contributed to this beautiful adventure: Philippe Véron, Dominique Kohler, Alain Vin, Georges Adrianzyk, Jean-Pierre Meunier, Gérard Knispel, Luc Weber, Daniel Lacroix, not to mention all our other friends at the Observatories of Geneva and Haute-Provence.

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The discovery of the exoplanets has given rise to an upsurge of new questions on the origin and formation of the stars and planets in the Universe. There are many challenges, and in order to meet them, our team has expanded considerably during the last five years. The present team is a gathering of people whose personal qualities match their scientific expertise. I would like to take the opportunity here to thank them all and confirm my appreciation of their qualities:

Jean-Luc Beuzit, Dominique Naef, Francesco Pepe, Christian Perrier, Nunō Santos, Jean-Pierre Sivan and Stéphane Udry.

I would also like to remind the reader that the discovery of the planet orbiting 51 Pegasus and its sister planets will not be enough in itself to bring all of the mystery of the exoplanets to light. It's only thanks to the help from many scientific disciplines that all these questions will one day be clarified. During the writing of this book, we have been able to take advantage of the expertise and observations of many specialists, who have played their part with patience and kindness. Thank you all: Jean-Philippe Beaulieu, Willy Benz, Xavier Delfosse, George Gatewood, Jean-François Lestrade, Andrew Lyne and Alexander Wolszczan.

Finally, this book is the result of a meeting between Pierre-Yves Frei, the science journalist, and myself, the astronomer. We together decided to set forth on this project. Hours and hours of interviews later, this stimulating collaboration has finally borne fruit. We hope that this work will be accessible to a wide readership. In any case, that's what we wanted. Happy reading!